Pilot Scale Development of a Septic-to-Sewer Conversion Prioritization Tool Using Analytical Hierarchy Process

Final Report

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Project Background, Anticipated Benefits, and Numbered Objectives

Onsite sewage treatment disposal systems (OSTDS) in Florida number approximately 2.4 million and serve roughly one third (1/3) of the state's population. Nutrient transport from these systems can lead to water quality degradation through processes such as nutrient loading and eutrophication. The Florida Department of Environmental Protection (DEP) has made progress at understanding which parameters influence septic drain field impacts on waterbodies, identifying parameters including but not limited to depth to groundwater, distance to surface waterbodies, hydraulic conductivity, OSTDS density and age, and topography (DEP Agreement No. AT006). While a step in the correct direction, it is vital to understand which parameters should be prioritized when assessing vulnerability of waterbodies to potential OSTDS pollution to guide initiatives such as septic-to-sewer conversions and OSTDS remediation plans being developed by municipalities. Even when parameters influencing nutrient transport from OSTDS are prioritized, data availability for parameters can be lacking and acquisition of a usable dataset is often difficult (cost, access, resource availability, etc.). Moreover, a coherent methodology is needed to define the relative importance of parameters to an overall model.

Multicriteria decision analysis (MCDA) can provide this methodology. MCDA is an accepted approach for organizing and assigning importance to parameters (Malczewski, 2006). Analytic Hierarchy Process (AHP) is the preferred MCDA technique when using geospatial data (Guerrón-Orejuela et al., 2023; Huang et al., 2011; Singh et al., 2018). AHP provides a systematic methodology to classify and prioritize among heterogenous parameters and ultimately define the parameter hierarchy that best represents fundamental processes (R. W. Saaty, 1987; T. L. Saaty, 1990). The coupling of AHP with GIS is a powerful combination for regional hydrogeologic research and decision-making and can be used to address complex, multidimensional problems. Together, GIS and AHP techniques allow for integrating different types of data, such as *in situ*, remote sensing, quantitative, qualitative, or spatial data from various sources (i.e., local, regional, or global) (Guerrón-Orejuela et al., 2023). This versatility is critical when data are not readily available, custom data acquisition is too costly or time-consuming, and expert knowledge is needed for accurate characterization of the landscape. While GIS-AHP techniques have not been previously utilized to understand OSTDS impacts to waterbodies, they have often been used to inform resource management of other water-related issues. Most recently, we used GIS-AHP techniques to map regional groundwater recharge potential to support prioritization of groundwater protection zones (Guerrón-Orejuela et al., 2023).

In this current project we have two objectives. First, we apply the AHP technique to weigh parameters and thus facilitate future development of a map of environmental risk posed by OSTDS. Second, we transfer the methodology for performing AHP analyses and guidance for applying the AHP results obtained in Objective 1 to a GIS-based screening tool, i.e., map, to DEP. When built, this screening tool will guide prioritization for septic-to-sewer conversion projects to serve the needs of DEP and other stakeholders in a pilot study area, i.e., St Lucie County, FL. It will join an ever-growing list of tools that empower decision-makers to have an informed dialog about OSTDS permitting and identification of high priority locations for conversion of septic to sewer.

Methods and Results of the AHP analyses performed on geospatial datasets in St. Lucie County

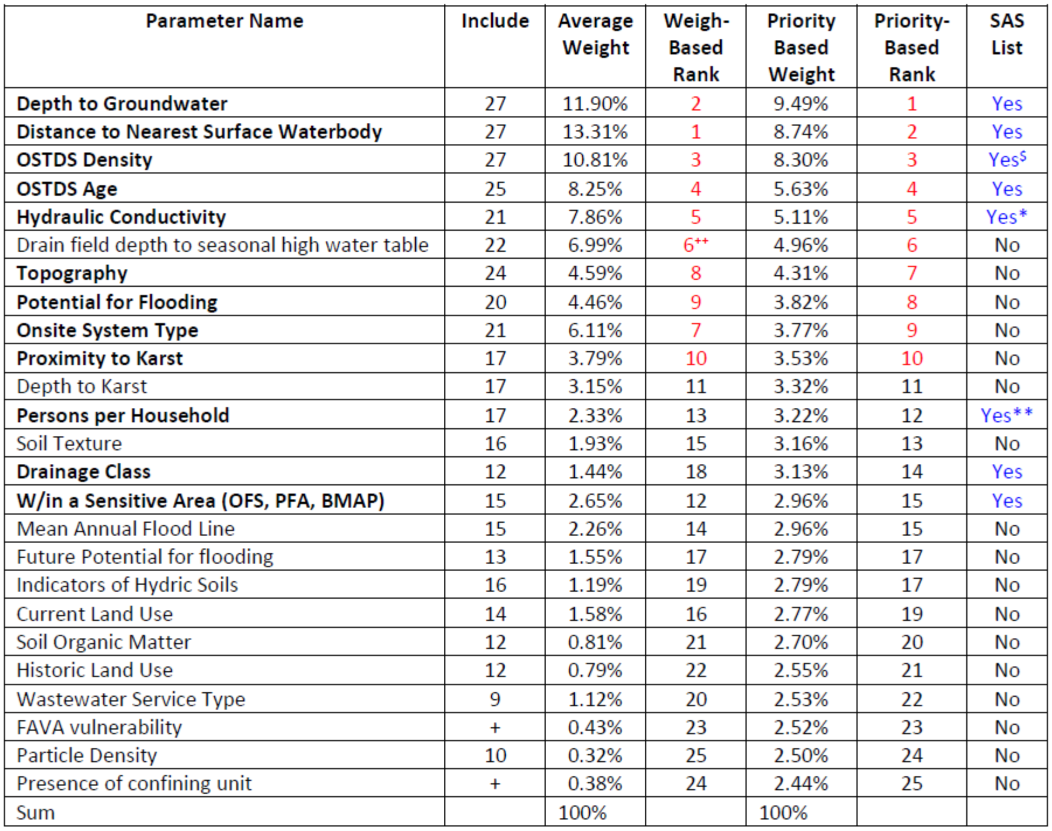
Resources Reviewed

We reviewed literature central to the focus of this contract, i.e., reports developed in a prior phase of this project prepared by CSS-SAS (DEP Agreement No. AT006), peer-reviewed articles focused on Multi-Criteria Decision Analysis (MCDA), Analytical Hierarchy Process (AHP), and dataset documentation. An annotated bibliography of approximately 36 MCDA/AHP and parameter/dataset resources reviewed is provided in Appendix 1. We additionally conferred with experts regarding additional dataset options and background detail, e.g., Dr. Ming Ye (FSU, RE: ArcNLET), Alan Baker, P.G. (FGS, RE: FAVA and depth to limestone or karst), Darrell Leach (Assistant State Soil Scientist RE: Soil Survey variable “Septic Tank Absorption Field” rating), Nicole Cortez (SFWMD RE Depth to Groundwater). Salient details of the CSS-SAS reports, dataset documentation, and personal communications regarding datasets are provided throughout this document.

Parameter Selection

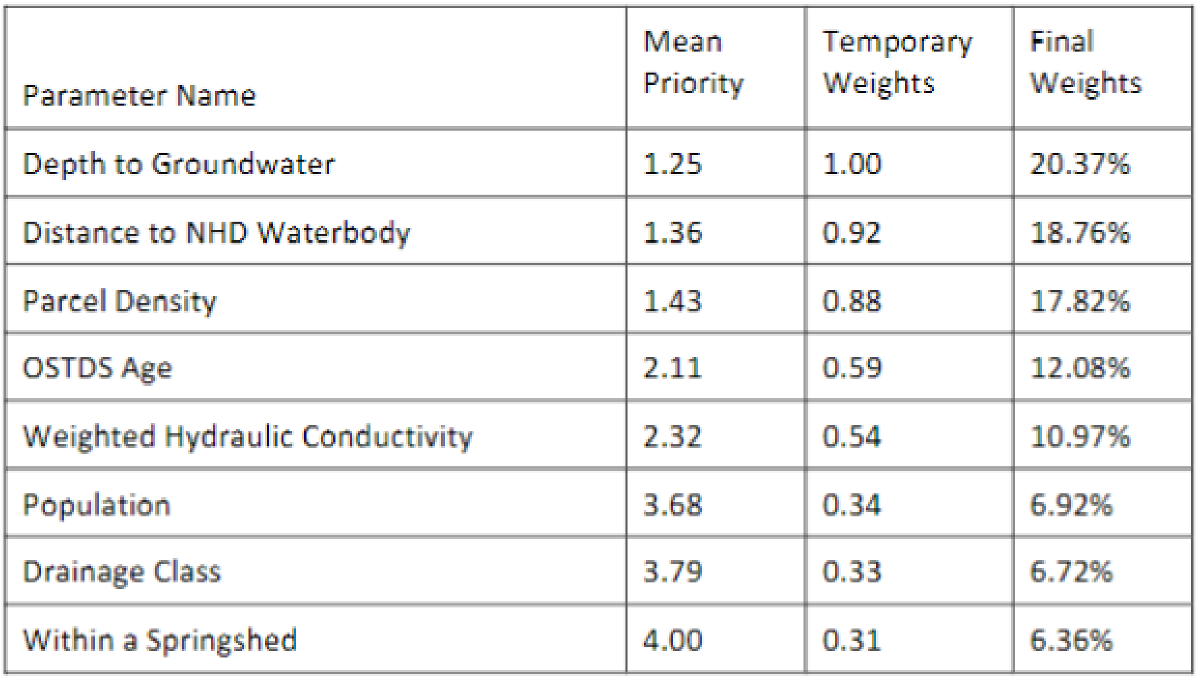
In a prior phase of this project (DEP Agreement No. AT006), the CCS-SAS team consulted with Subject Matter Experts to develop and weigh a list of parameters to consider when assessing the risk of existing OSTDS on downgradient waters (Table 1). We began our parameter selection process by reviewing documentation of that effort provided to us by FDEP OEAT. We noted that of the ten parameters determined by Subject Matter Expert during CCS-SAS workshops held on May 5, 2022, and May 6, 2022 (Table 1), only 4 were advanced to the final CCS-SASS final model list (Table 2). According to their report, if SAS did not have a dataset corresponding to a top ten parameter listed by the SMEs, that parameter was not advanced (see “SAS List” Table 1).

Table 1. This table is reproduced from CCS-SAS Task 2 Deliverables. It was produced by CCS-SAS in a prior phase of this project (FDEP Agreement # AT006 Workshop Report, Task 2 Deliverable)**.** It includes the list of parameters discussed during the CCS-SAS workshop and the average weights and ranks of these parameters they derived from the participants’ individual work completed at the start of day 2 of the CCS-SAS workshop May 6,2022. We have reproduced it here as a record of the parameters we considered.



Parameter Name	Include	Average Weight	Weigh-Based Rank	Priority Based Weight	Priority-Based Rank	SAS List
Depth to Groundwater	27	11.90%	2	9.49%	1	Yes
Distance to Nearest Surface Waterbody	27	13.31%	1	8.74%	2	Yes
OSTDS Density	27	10.81%	3	8.30%	3	Yes$
OSTDS Age	25	8.25%	4	5.63%	4	Yes
Hydraulic Conductivity	21	7.86%	5	5.11%	5	Yes*
Drain field depth to seasonal high water table	22	6.99%	6++	4.96%	6	No
Topography	24	4.59%	8	4.31%	7	No
Potential for Flooding	20	4.46%	9	3.82%	8	No
Onsite System Type	21	6.11%	7	3.77%	9	No
Proximity to Karst	17	3.79%	10	3.53%	10	No
Depth to Karst	17	3.15%	11	3.32%	11	No
Persons per Household	17	2.33%	13	3.22%	12	Yes**
Soil Texture	16	1.93%	15	3.16%	13	No
Drainage Class	12	1.44%	18	3.13%	14	Yes
W/in a Sensitive Area (OFS, PFA, BMAP)	15	2.65%	12	2.96%	15	Yes
Mean Annual Flood Line	15	2.26%	14	2.96%	15	No
Future Potential for flooding	13	1.55%	17	2.79%	17	No
Indicators of Hydric Soils	16	1.19%	19	2.79%	17	No
Current Land Use	14	1.58%	16	2.77%	19	No
Soil Organic Matter	12	0.81%	21	2.70%	20	No
Historic Land Use	12	0.79%	22	2.55%	21	No
Wastewater Service Type	9	1.12%	20	2.53%	22	No
FAVA vulnerability	+	0.43%	23	2.52%	23	No
Particle Density	10	0.32%	25	2.50%	24	No
Presence of confining unit	+	0.38%	24	2.44%	25	No
Sum		100%		100%		

Table 2. This table is reproduced from CCS-SAS Task 3 Deliverables. It was produced by CCS-SAS in a prior phase of this project (FDEP Agreement # AT006). It includes the final CCS-SAS parameter list and weights. We have reproduced it here for ease of comparison with the parameter list and weights resulting from the current phase of the project. Note that many of the top ten parameters in Table 1 are missing from Table 2.



Parameter Name	Mean Priority	Temporary Weights	Final Weights
Depth to Groundwater	1.25	1.00	20.37%
Distance to NHD Waterbody	1.36	0.92	18.76%
Parcel Density	1.43	0.88	17.82%
OSTDS Age	2.11	0.59	12.08%
Weighted Hydraulic Conductivity	2.32	0.54	10.97%
Population	3.68	0.34	6.92%
Drainage Class	3.79	0.33	6.72%
Within a Springshed	4.00	0.31	6.36%

We reviewed closely the list of parameters identified by the SMEs (Table 1) rather than the short list included in the CCS-SAS model (Table 2) because 1) we could readily identify geospatial datasets that could be used to derive some of the top ten CCS-SAS parameters, 2) new geospatial datasets are quickly being developed so some missing now may be developed soon, and 3) in the AHP methodology it is easier to remove a parameter after the pairwise comparison step than it is to add one after comparisons are complete. We selected for advancement (Table 3) the top 12 parameters listed in Table 1, which had been identified by a minimum of 17 SMEs during the CCS-SAS project but combining two sets of closely related parameters (depth to karst/proximity to karst and depth to groundwater/depth of drainfield to groundwater), bring the total list to ten.

Table 3. Parameters discussed by SMEs and other meeting attendees during the June 5, 2023 meeting held by USF-OEAT. During this meeting, USF suggested, and SMEs agreed, to remove the OSTDS parameters from this list. SMEs additionally suggested removing parcel density. Those four parameters are considered important but will be handled separately, see text.

Parameter
Distance to waterbody
Depth to groundwater
Hydraulic conductivity
Potential for flooding
Topography (Slope)
Depth to karst
~~Parcel density or Persons in household~~
~~OSTDS age~~
~~OSTDS density~~
~~OSTDS type~~

We presented the list of parameters in Table 3 to attendees, including subject matter experts (SMEs), during a 4-hour virtual workshop on June 5th, 2023. We additionally suggested removing the three parameters that address OSTDS characteristics from the list in an effort to limit the list to physical landscape parameters, thus ensuring the final map will continue to be useful even as OSTDS systems are installed, removed, or updated (Table 3). Attendees agreed with this approach and additionally suggested removing "parcel density" from the list for similar reasons. It was agreed these four parameters are important, but it would be advantageous to handle them separately, perhaps as an additional overlay, that could be readily updated.

Attendees represented academia, private industry, state, and local agencies (Appendix 2) and included people identified by the OEAT-USF team as SMEs in OSTDS and hydrologic systems. The workshop was divided into 5 sections (Appendices 3 and 4). The first section was dedicated to presenting project background the full list of parameters in Table 3. In the second section, we presented the benefits and use of MCDM and AHP in solving complex environmental questions. We focused on the AHP method and gave an overview of the pairwise comparison procedure and model development. Next, we presented an example of AHP in practice, focusing on our recent use of AHP to develop a recharge potential map (Guerrón-Orejuela et al., 2023). Finally, attendees discussed the ten parameters listed in Table 3 and this list was reduced to 6 as described above.

AHP Methodology and Analysis

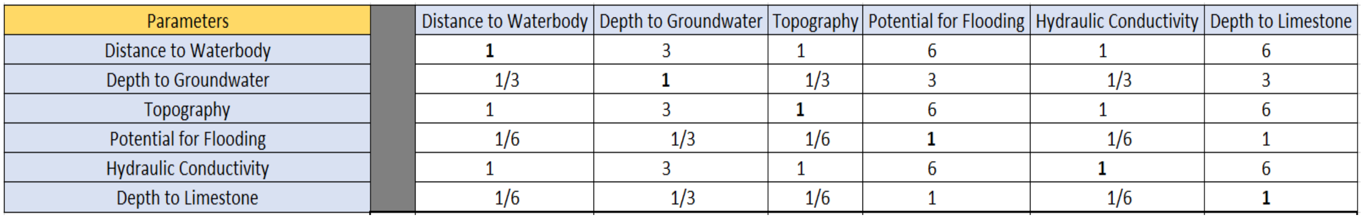
During the workshop, SMEs were asked to individually perform pairwise comparisons of the parameters listed in Table 3. We provided attendees with pairwise comparison data sheets (see Appendix 5) and remained available for questions. They evaluated each pair, initially determining whether one member of the pair was more important than the other and then using a relative importance scale to describe how much more important one parameter was than the other (Table 4).

Table 4. Relative importance scale (R. W. Saaty, 1987).

Scale	1	3	5	7	9
Importance	Equally	Moderately	Strongly	Very Strongly	Extremely
Even numbers are also possible in the scale and express intermediate importance.					

Additionally, attendees were provided space for additional comments and prompted to respond to two questions concerning regionalization: 1) Would your parameters be different in different regions? 2) Would you rank the parameters different in different regions? Twelve subject matter experts (SMEs) in attendance at the meeting completed the pairwise comparisons and submitted them via email by the end of business day on Friday, June 9, 2023. Their responses were entered into spreadsheets for further analysis. Of the respondents who answered the prompted questions, 91% (10/11) answered in the affirmative. All comments have been listed in Appendix 6.

We used the information in each completed worksheet to construct corresponding pairwise comparison matrices. We transcribed the importance values assigned by the SMEs into the matrix and added the reciprocal of those values to the appropriate cells (Figure 1) (R. W. Saaty, 1987). Appendix 7 contains the comparison matrices for each respondent.



Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	3	1	6	1	6
Depth to Groundwater		1/3	**1**	1/3	3	1/3	3
Topography		1	3	**1**	6	1	6
Potential for Flooding		1/6	1/3	1/6	**1**	1/6	1
Hydraulic Conductivity		1	3	1	6	**1**	6
Depth to Limestone		1/6	1/3	1/6	1	1/6	**1**

Figure 1. Example of a comparison matrix based on pairwise comparison data provided by one workshop participant.

According to the AHP methodology, the principal eigenvector, $\vec{p}$, is the desired priorities vector. We calculated $\vec{p}$ by normalizing the elements in each column of the comparison matrix and then averaging over each row (R. W. Saaty, 1987). We estimated the largest eigen value, λmax, by adding the columns of the comparison matrix and multiplying the resulting vector by $\vec{p}$.

The difference between $\boldsymbol{\lambda max}$ and the number of spatial datasets (*n*) is a measure of the inconsistency of the comparison matrix. We calculated the consistency index (*CI*) as per equation (1) (R. W. Saaty, 1987), where *CI* is the consistency index, *n* is the number of spatial datasets.

$$\boldsymbol{CI = \frac{\lambda max - n}{n - 1}} \tag{1}$$

We also used the random consistency index (RI), a table-based value dependent on the number of variables used, to calculate the consistency of the comparison matrix, which is a measure of how far the comparison matrix is from total consistency (T. L. Saaty, 1990, 2003). For our analysis *n* = 6, which corresponds to RI = 1.24 (Table 5).

Table 5. Random Consistency Index based on the number of parameters used (R. W. Saaty, 1987).

n	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41

n number of thematic layers, RI random consistency index

Finally, we calculated the consistency ratio (2), which measures the consistency of the judgment used during the pairwise comparison based on transitive property.

$$\boldsymbol{CR = \frac{CI}{RI}} \quad (2)$$

We used the process described above to construct comparison matrices that reflected the responses provided by each of the twelve SME respondents and to assess whether they were internally consistent. We noted that all but three SME responses had an internal consistency ratio of less than 0.15. We contacted those three respondents to determine whether they would like to review their answers for mis-entries. Two of the three responded, but only one was able to re-evaluate her responses within the project timeline. Her modified pairwise comparisons newly fell below 0.15.

We next performed a series of tests to determine whether retaining the information provided by other two respondents would compromise the consistency of the overall model. We calculated the CR of the overall model with and without the two other sets of comparisons provided and determined there was very little change. We additionally noted the order of the model parameters was unaffected by the addition of those responses. Thus, we included all 12 pairwise comparison data sheets returned to us in the model. A summary table of calculated weights based on participants' responses can be found in Appendix 8.

AHP Results and Final Model Design

We built the final model by calculating the geometric mean of the data provided in the individual responses. We created a pairwise comparison matrix for the entire model, following a procedure much like the one used to create matrices for each participant in the previous step. We calculated the geometric mean of all responses for each pairwise comparison, then we inserted the reciprocals of the geometric means in the transpose of each pairwise comparison to complete the matrix (Aczél & Alsina, 1987; Aczél & Saaty, 1983). Subsequently, for this matrix, we calculated all the consistency metrics as described above. Models with CR values lower than 0.1 are considered internally consistent (R. W. Saaty, 1987). *The consistency ratio of the final model was 0.01, indicating high internal consistency.*

The model results (Table 6) indicate Distance to waterbody has the greatest influence, with a weight of 30%. Depth to groundwater, Hydraulic conductivity, Potential for flooding, and Topography have the subsequent greatest influence on the model, with weights of 21.6%, 20.7%, 10.9%, and 9.8%, respectively. Depth to limestone has the least influence on the model, with a weight of just 7.0%. Participant comments (Appendix 6) suggest that many would assign a higher weight to Depth to limestone in other regions of Florida.

Table 6. Model Results

Parameter	Weight (%)
Distance to waterbody	30.0
Depth to groundwater	21.6
Hydraulic conductivity	20.7
Potential for flooding	10.9
Topography (Slope)	9.8
Depth to karst	7.0

Discussion

This Septic-to-Sewer conversion prioritization framework reveals that waterbody vulnerability to OSTDS in St. Lucie County is primarily driven by distance to waterbody, then by depth to groundwater, hydraulic conductivity, potential for flooding, topography, and depth to limestone, in that order. These results concur with other studies conducted, most notably with the study conducted by CCS-SAS under DEP Agreement No. AT006.

We identified priority geospatial datasets that can be used to transfer the model (i.e., parameter weights) to a geospatial platform and rate locations by the degree of environmental risk posed by OSTDS (Appendix 9). When there were multiple options of geospatial datasets to represent a parameter, we prioritized those with complete coverage in the target study area. In the following paragraphs we discuss several additional considerations and provide alternatives to overcome some data gaps and limitations.

Although the parameter with the highest calculated weight is distance to waterbody, we would like to emphasize the importance of the canal system in this landscape. Both NHD waterbodies and NHD flowlines should be included in this analysis. In St. Lucie County large canals are common and have the potential to convey large amounts of water downgradient (Figure 2).

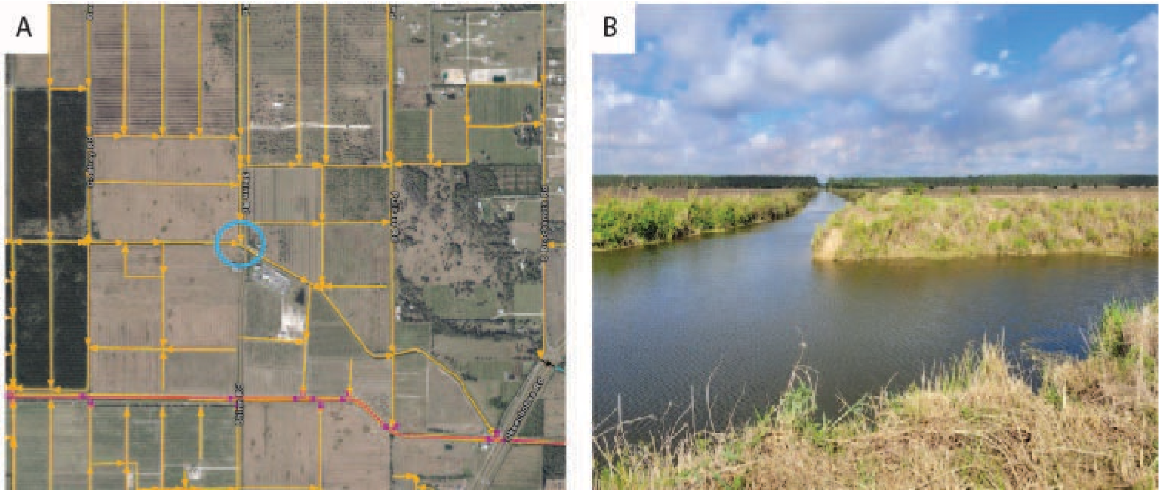


Figure 2. Example of the features included as “flowlines” in the National Hydrography Dataset. The canal system in St Lucie County is extensive and has the potential to convey large quantities of water downgradient and ultimately to the Indian River Lagoon. Panel A: NHD flowlines are depicted in orange. Panel B: Photograph looking east from the location indicated by the blue circle in Panel A. Photograph by Kai Rains 4/2023. Panel A Source: https://www.arcgis.com/home/webmap/viewer.html?url=https%3A%2F%2Fhydro.nationalmap.gov%2Farcgis%2Frest%2Fservices%2Fnhd%2FMapServer&source=sd.

The parameter that has the second highest weight in the model is depth to groundwater. In a previous project, CCS-SAS used the Florida Aquifer Vulnerability Assessment (FAVA) model to estimate depth to groundwater, and this data source was again suggested by SMEs during the June 5, 2023, meeting. However, we subsequently viewed the data and determined there were numerous data gaps across the State of Florida (Figure 3). We reviewed the literature and additionally found the authors estimate the error is quite large, i.e., average vertical uncertainty 7 ft, with a maximum error ranging from -34 ft to +31 ft (Arthur et al., 2005).

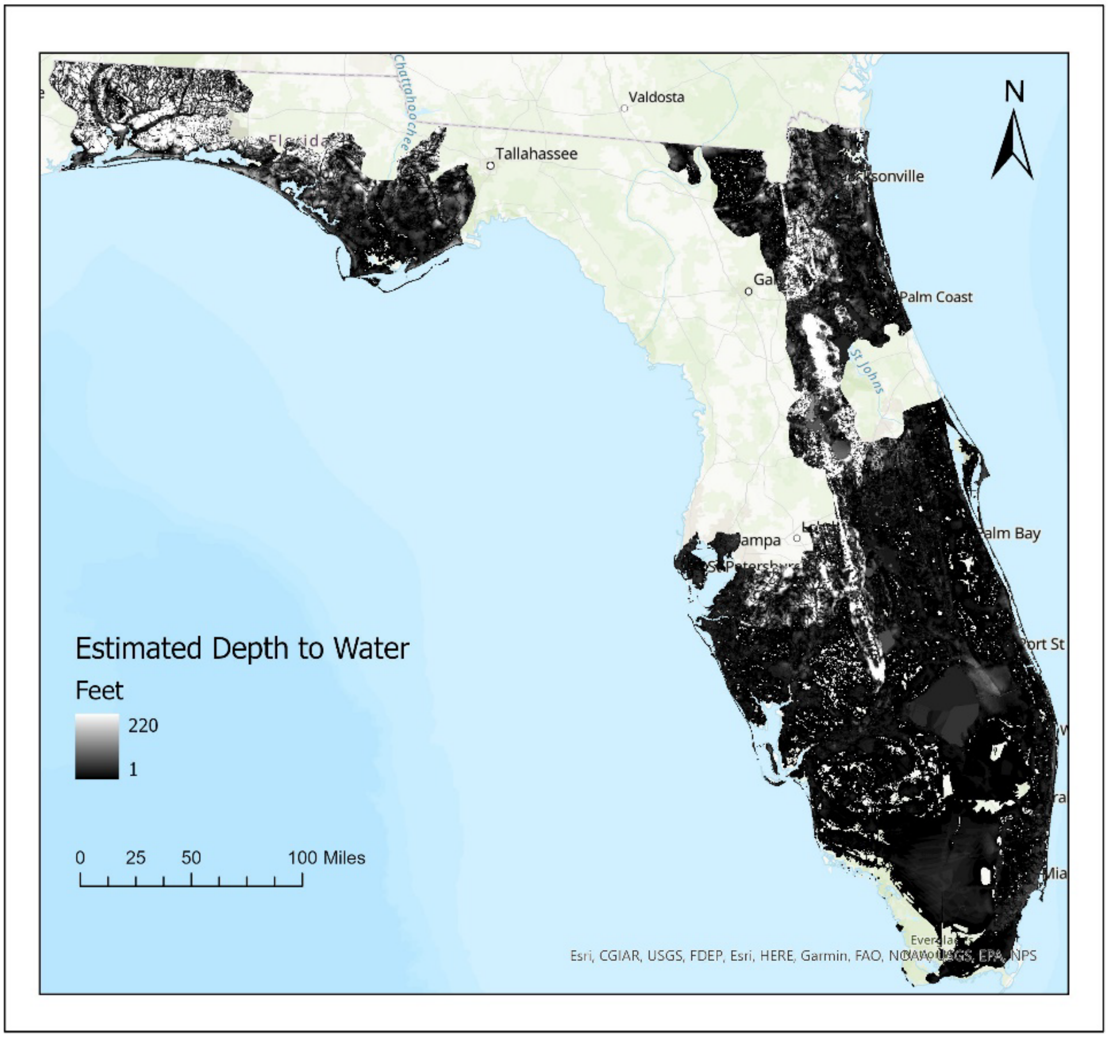


Figure 3. Estimated Depth to Water - Surficial Aquifer. Map showing the depth to water in the State of Florida as predicted by FAVA. Areas where the base map is visible are areas where the predicted surface for the water table erroneously exceeds the land level. These locations, which include many areas across the State of Florida, are treated as having data gaps.

We contacted the Florida Geological Survey and learned that the gaps in coverage are related to areas where the predicted surface for the water table aquifer exceeded land surface (Alan Baker, FGS, personal communication, June 20, 2023). When FAVA was initially developed, the land surface DEM that was available statewide was derived from the USGS 1:24k topographic maps (Arthur et al., 2005). However, there is newly available Lidar derived DEM data that can be used to refine this product and water table elevation data may similarly be enhanced since initial model development. If FAVA is fully updated in the future, it may provide a more accurate reference than the SSURGO data (see below) for Depth to Groundwater.

Another potential source for depth to groundwater data is ArcNLET. ArcNLET does provide an estimate for depth to groundwater (Rios et al., 2013) that warrants further examination, but it has not been fully developed in the study area (Ming Ye, FSU, personal communication, June 11, 2023).

Given the current limitations associated with FAVA and ArcNLET, we suggest using the Soil Survey Geographic Database (SSURGO) for depth to groundwater geospatial data. The SSURGO dataset is readily available for download and has coverage for the entire State of Florida. SSURGO is an accepted data source. During the June 5, 2023, workshop, SSURGO was discussed and widely accepted by SMEs as a data source for Hydraulic Conductivity. It is also integral to the ArcNLET models. However, one potential drawback of this data set as a source for depth to groundwater is that it identifies depth to groundwater up to a depth of 80 inches, beyond that it only reports depth to groundwater as greater than 80 inches. However, a depth of 80 inches is consistent to the depth septic site inspectors are required to examine soil profiles for indicators of seasonal water table depth (Fla. Admin Code R. 64E-6).

The third highest weighted parameter in the model is hydraulic conductivity. We suggest, as did the CCS-SAS final report, that the source of data for the parameter hydraulic conductivity be the SSURGO database. However, we would like to point out that the values expressed in this dataset represent vertical hydraulic conductivity, but not lateral i.e., horizontal, hydraulic conductivity. We identify lateral hydraulic conductivity as a data gap in this project. We suggest additional review of the ArcNLET modeling procedures and products to determine whether ArcNLET may be a suitable data source for lateral hydraulic conductivity in the future. Currently, ArcNLET modeling has not been completed across the study area.

The fourth highest weighted parameter is potential for flooding. During the June 5, 2023, workshop, the Federal Emergency Management Agency's (FEMA) National Flood Hazard Layer (NFHL) was suggested by SMEs as a data source for potential for flooding. NFHL is a geospatial database that contains current effective flood hazard data and can be used to better understand the level of flood risk and type of flooding in an area of interest.

The fifth highest weighted parameter is topography. The FL Peninsular LiDAR Project (including the Hurricane Michael Supplemental collection) covers most of the state of Florida (this project collected LiDAR data for 58 counties). Data for the remaining counties was collected as part of other projects. These newly developed datasets can be the source of elevation data and can be used to calculate the slope of the management unit's centroid to the waterbody of interest.

The parameter with the smallest weight in the model is Depth to limestone. Depth to limestone is the only parameter for which there is no geospatial dataset available. However, according to Alan Baker (FGS, personal communication to Moses Okonkwo, FDEP-OEAT, June 12, 2023):

> "You could use the Surficial Geologic map of Florida and query out any of the Limestone entries in the Lithology column as a way to display areas of the state where limestone(s) are near land surface. As a rule, the Surficial Geology map identifies the first recognizable lithostratigraphic unit occurring within 20 feet of land surface. If the shallowest occurrences of the karstic limestone is 20 feet or less below land surface, the limestone formation was mapped. If the limestone is more than 20 feet below land surface, an undifferentiated siliciclastic unit was mapped. Of particular note is that this map is not a karst or sinkhole hazard map.
>
> The Lithologies you would query are: [Clay, sand, limestone], [Dolostone, limestone, sand, clay], [Dolostone limestone, sand, clay, phosphate], [Dolostone, sand, clay, phosphate], [Framestone], [Limestone, coquina, sand], [Limestone, dolostone], [Limestone, dolostone, sand, clay], [Limestone, sand], [Limestone, sand, clay], [Sand, clay, dolostone, phosphate], [Sand, clay, limestone, dolostone, phosphate], and [Sand, clay, phosphate, dolostone]. "

The geospatial datasets presented above can be integrated using the framework developed during this project to map locations by the degree of environmental risk posed by OSTDS. Water quality is one of Florida's biggest environmental issues and therefore it has become a priority for agencies like the Florida Department of Environmental Protection. In 2019 the Blue-Green Algae Task Force identified that for water quality improvement, converting septic to sewer should be a priority. Furthermore, DEP identified there are 2.6 million OSTDS, and some may no longer be well suited to their environment. But it is not feasible to convert all OSTDS to sewer or enhanced systems at once. Therefore, DEP has been working to identify tools that could help assess and prioritize projects statewide.

Frameworks like the one developed through this project are important for increasing the awareness and enabling effective resource management. To our knowledge, no previous studies have coupled GIS and AHP to map locations by the degree of environmental risk posed by OSTDS, although these methods have often been applied successfully to other related issues in hydrology (Appendix 1). Here, we use GIS and AHP to construct a model framework based on remote sensing data and SME knowledge. The screening tool that will be created upon complete implementation of this framework will join an ever-growing list of tools, such as those based on detailed site-specific modeling, that empower decision-makers to have an informed dialog about how to prioritize septic to sewer conversion projects.

In conclusion, we note that the model framework developed during this project, which was derived from an AHP process, is internally robust and suitable for use in the next step of this project.

Drawbacks or possible biases of the model results

Combining AHP with powerful spatial and statistical analysis within a GIS environment creates a valuable tool for water resources management. This method allows qualitative and quantitative criteria to be considered in decision-making. AHP’s biggest weakness is the potential for evaluator bias when establishing criteria and developing the pairwise comparison matrix. We addressed this weakness by reviewing relevant literature and relying on SMEs, effectively crowdsourcing the list of relevant parameters and their wights in the model.

Furthermore, during the workshop we asked SMEs to perform their pairwise comparisons focusing on the theoretical parameter itself, in other words not to weigh parameters based on a specific or available dataset. This is important because if the weights are assigned based on the theoretical importance of a parameter, these weights will carry over in time, regardless of whether a new or updated dataset becomes available. This, however, adds additional steps in the model development process because it requires model developers to identify the different dataset available for each parameter and further consult with SMEs regarding the validity of each dataset.

As stated earlier, during the workshop SMEs were asked two questions concerning regionalization: 1) Would your parameters be different in different regions? 2) Would you rank the parameters different in different regions? Of the respondents who answered the prompted questions, 82% (9/11) answered yes to question 1, and 91% (10/11) answered in the affirmative to question 2. This indicates that this AHP exercise may need to be conducted multiple times for different regions in Florida (perhaps based on the physiographic regions outlined in the FAVA report).

Instructions on the transfer of the model into a geospatial platform

The USF-OEAT team has held multiple instructional, capacity building, and hand-off meetings to review the steps taken to design and test the structure of the model and to provide a roadmap for the transfer of the model into a geospatial platform (see Appendix 10 for a detailed list of all instructional meetings). The instructions below describe the procedure for transferring a set of geospatial datasets to a single map. Prior to initiating this sequence of steps, weights are assigned to conceptual parameters, thus creating a "model" (e.g., Table 6), and the most suitable geospatial datasets for each of these parameters is selected. When choosing the most suitable geospatial datasets, factors to consider include the following: data completeness (no gaps in data), date of creation or latest update date, frequency at which data is updated, data accuracy or reliability, data applicability (is this data used by OSTDS professionals and/or regulatory entities), data availability (is this dataset available statewide in case of project expansion). The geospatial datasets and work platform (e.g., ArcPro) should additionally be checked for quality considerations, such as consistent projection. Once complete, follow the steps outlined below:

1. Define the size of the management unit to prepare for rasterizing the geospatial datasets to a common grid size. Consider, for example, the following:
    a. Size of property/parcel at which management decisions will be made
    b. Computation time
    c. Resolution of geospatial datasets
2. Calculate and transform geospatial datasets as needed to reflect the parameter identified by the Subject Matter Experts. For example, the distance to waterbody parameter may be derived from the distance between the centroid of the grid cell to the edge of the nearest NHD large-scale waterbody or flowline.
3. Assign importance scale values to the data within each geospatial dataset. Often the data are first grouped into 5 subgroups each of which is assigned a value of 1, 3, 5, 7, or 9 (Table 3). The procedure for designating subgroups is slightly different for continuous versus categorial data. A common method used with continuous physical data in hydrogeologic studies is natural breaks classification (Abijith et al., 2020; Arulbalaji et al., 2019; Guerrón-Orejuela et al., 2023). An example of this process can be found in Guerrón-Orejuela et al. 2023, see "slope". In contrast, for categorical data (e.g., "land use/land cover in Guerrón-Orejuela et al. 2023), subgroups are designated by expert knowledge and possibly refined, if needed, through sensitivity analyses.
4. Once the data subgroups have been finalized, use expert knowledge to assign an importance value (Table 3) to each of the subgroups. In Guerrón-Orejuela et al. (2023), this step is referred to as "relative ranking of data classes within spatial dataset".
5. Rasterize the geospatial datasets and assign the corresponding importance value to each pixel. Conduct standard QA/QC checks (e.g., consistency of projection).
6. Produce the final map by assigning weights (see AHP model results) to each of the geospatial datasets corresponding to the model parameters. In ArcGIS Pro the Weighted Overlay Tool will facilitate this step.
7. Validate the final product through comparison to modeling (e.g., ArcNLET) or to field data. For example, use field observations or modeling results to identify locations where OSTDS has impacted water quality. Determine the frequency with which the map

accurately rates these locations as “high risk”. Complete a confusion matrix to quantify the verification results.

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Appendix 1

Resources Reviewed.

Item #	Title	Links	Author(s)	Date Published or Date Accessed	Summary	Application
1	Multi-criteria decision analysis for delineation of groundwater potential zones in a tropical river basin using remote sensing, GIS and analytical hierarchy process (AHP)	https://www.sciencedirect.com/science/article/abs/pii/S2352801X18300237	Achu, A. L., Thomas, J., & Reghunath, R	2020	Using remote sensing, GIS, and the AHP method, the Manimala River Basin (MRB) was defined. The GWPZs were established using geoenvironmental parameters such as land use/cover, geomorphology, lithology, soil, slope, lineament density, and drainage density. In ArcGIS, a multi-criteria decision analysis was carried out utilizing weights produced by the AHP method. The GWPZs were classed into four classes, with good to very good groundwater potential present in 50% of the basin area.	GIS-AHP application
2	Delineating of groundwater potential zones based on remote sensing, GIS and analytical hierarchical process: a case of Waddai, eastern Chad	https://link.springer.com/article/10.1007/s10708-020-10160-0	Al-Djazouli, M. O., Elmorabiti, K., Rahimi, A., Amellah, O., & Fadil, O. A. M.	2020	The Waddai region can benefit from groundwater exploration using geospatial technology (RS, GIS, and AHP). The GWPZ has been divided into four categories: extremely low, low, moderate, and good. This study delineates GWPZs based on multiple layers of thematic maps. The drawbacks of this strategy depend on the elements that are chosen and how much weight is given to each one. It could be employed in semi-arid and dry environments.	GIS-AHP application
3	GIS and AHP Techniques Based Delineation of Groundwater Potential Zones: a case study from Southern Western Ghats, India	https://www.nature.com/articles/s41598-019-38567-x	Arulbalaji, P., Padmalal, D., & Sreelash, K.	2019	In a small, humid tropical river basin in South India, this study aimed to define the groundwater potential zones. The study region was divided into five unique ground water potential zones, such as extremely high, high, moderate, low, and poor, using 12 theme layers. The map was verified using data on groundwater flow and groundwater prospects, giving decision-makers insights for effective groundwater planning and management for urban and agricultural uses.	GIS-AHP application
4	Application of remote sensing and GIS to assess groundwater potential in the transboundary watershed of the Chott-El-Gharbi (Algerian–Moroccan border)	https://link.springer.com/article/10.1007/s13201-022-01663-x	Derdour, A., Benkaddour, Y., & Bendahou, B.	2022	The groundwater potential zone in the Chott-El-Gharbi transboundary watershed was defined in this study using a mix of Remote Sensing, Geographic Information Systems (GIS), and Analytical Hierarchy Process (AHP). The findings revealed that 60.57% of the research region had a medium groundwater potential, while 18.49% fell into "excellent" to high zones. High drainage densities, quaternary landforms, low slopes, and low altitudes were the locations of the most probable prospective zones. The method's accuracy was 72.41%.	GIS-AHP application
5	Conventional System Inspection Requirements and Field Standardization	https://www.floridahealth.gov/environmental-health/onsite-sewage/training/_documents/4b_4c_inspections-handout.pdf	Florida Department of Health	Date accessed: 6/26/2023	Presentation outlining inspection requirements for Spetic Tank sites.	OSTDS specific
6	Mapping Groundwater Recharge Potential in High Latitude Landscapes Using Public Data, Remote Sensing, and Analytic Hierarchy Process	https://www.mdpi.com/2072-4292/15/10/2630	Guerrón-Orejuela, E. J., Rains, K. C., Brigino, T. M., Kleindl, W. J., Landry, S. M., Spellman, P., Walker, C. M., & Rains, M. C	2023	This GWRP model shows that slope, followed by land cover, soil texture, precipitation, geology, and drainage density, determines the study area's capacity for groundwater recharge. High-permeable surficial sediments, generally low gradients, and predominantly natural land cover are present in areas with the highest GWRP values. The model demonstrates that proglacial lake bottom sediments and flood plains are where groundwater recharges the most. Using AHP in conjunction with robust geographical and statistical analyses, a useful tool for managing water resources is produced.	GIS-AHP application
7	Delineation of zones and sites for artificial recharge of groundwater in dry land Barind Tract, Bangladesh using MCDM technique in GIS environment	https://link.springer.com/article/10.1007/s40899-022-00713-1	Hasan, Md. T., Jahan, C. S., Rahaman, Md. F., & Mazumder, Q. H.	2022	With potential for groundwater recharge, the land has dendritic drainage patterns and is good for surface water conservation. Barind Clay dominates the surface lithology, which is unfavorable for groundwater recharge. The "moderately suitable" and "highly suitable" zones on the suitability map for artificial recharge sites indicate locations for check dams, while the "unsuitable" zones suggest MAR facilities and percolation tanks as artificial recharge structures.	GIS-AHP application
8	Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends	https://www.sciencedirect.com/science/article/abs/pii/S0048969711006462	Huang, I. B., Keisler, J., & Linkov, I.	2011	Over the past two decades, the use of MCDA tools in environmental research has increased dramatically, with applications that demand integrated environmental assessment, stakeholder involvement, and strategy creation being more prevalent. All of the main MCDA techniques (MAUT, outranking, and AHP) have been applied; AHP/ANP makes up about half of the 312 papers. The same alternatives are favored by all MCDA tools.	MCDA Methods
9	Groundwater recharge potential zonation using an ensemble of machine learning and bivariate statistical models	https://www.nature.com/articles/s41598-021-85205-6	Jaafarzadeh, M. S., Tahmasebipour, N., Haghizadeh, A., Pourghasemi, H. R., & Rouhani, H.	2021	In order to find prospective groundwater recharge zones for the Marboreh watershed in the Iranian province of Lorestan, this study integrates FR and MA models. With AUC and CCI values of 0.990 and 0.907, the results demonstrate that ensemble classifier with scenario 5 is more accurate than individual models. Based on the soil, lithology, aspect, and elevation, different GWR potential zones exist. The degree of input uncertainty affects how accurate the desired outcomes are. In this investigation, different groundwater recharge potentials were found using a double-ring infiltrometer. To collect greater amounts of surface water, recharge aquifers, and manage water deficits, it is advised to build aquifer recharge facilities in regions with "high" and "very high" percolation potential. The study area heavily depends on groundwater abstraction to support irrigated agriculture.	GIS-AHP application
10	A fuzzy based MCDM–GIS framework to evaluate groundwater potential index for sustainable groundwater management - A case study in an urban-periurban ensemble, southern India	https://www.sciencedirect.com/science/article/abs/pii/S2352801X20303787	Jesiya, N. P., & Gopinath, G.	2020	The fuzzy-AHP-GIS strategy utilized in the study applied a full integral method for comparing geo-environmental features and combined groundwater controlling criteria and sub-criteria to a unique hierarchical level. In GWPZ decision-making, the results indicated that geomorphology and slope were of the utmost relevance. Due to urban activities and hydrogeological settings, GWPZ was good to very good in 65% of the urban area.	GIS-MCDA application
11	GIS-based multicriteria decision analysis: a survey of the literature	https://www.tandfonline.com/doi/full/10.1080/13658810600661508	Malczewski, J.	2007	In order to provide mechanisms for disclosing decision-makers' preferences, find and explore compromise possibilities, and aid users in comprehending the outcomes of GIS-based decision-making processes, GIS-MCDA is a crucial subfield of research in GIScience. However, there are a number of issues, difficulties, and patterns in the research relating to the advancements in geographic information systems and spatial analysis, as well as the conceptual and practical validation of the use of MCDA in practical spatial problems.	GIS-MCDA overview
12	Determination of Potential Aquifer Recharge Zones Using Geospatial Techniques for Proxy Data of Gilgel Gibe Catchment, Ethiopia	https://www.mdpi.com/2073-4441/14/9/1362	Mengistu, T. D., Chang, S. W., Kim, I.-H., Kim, M.-G., & Chung, I.-M.	2022	In order to locate possible aquifer recharge zones in the Gilgel Gibe watershed, Ethiopia, this study used GIS, RS, and MCDA. Lithology (20.2%), lineament density (8.8%), slope (5.4%), elevation (5.1%), soil (8.8%), LULC (15.3%), rainfall (14.5%), drainage density (7.2%), topographic position index (7.5%), and topographic wetness index (7.3%) were the factors that were most significant, in that order. The groundwater potentiality of the created map was divided into five categories: very high, high, moderate, low, and very low. The results are crucial in that they offer information that can be used to simplify decision-making procedures for effective management of groundwater aquifers.	GIS-AHP application
13	Methods for Estimating Water-Table Elevation and Depth to Water Table	https://www.bing.com/ck/a?!&&p=e218d47ead45b981JmltdHM9MTY4NzQ3ODQwMCZpZ3VpZD0zMmFiYzllOS1jMWNjLTYzNDQtMWUzNy1kYjIzYzBlZDYyY2UmaW5zaWQ9NTIwNw&ptn=3&hsh=3&fclid=32abc9e9-c1cc-6344-1e37-db23c0ed62ce&psq=Methods+for+Estimating+Water-Table+Elevation+and+Depth+to+Water+Table&u=a1aHR0cHM6Ly9maWxlcy5kbnIuc3RhdGUubW4udXMvd2F0ZXJzL2dyb3VuZHdhdGVyX3NlY3Rpb24vbWFwcGluZy9ndy9ndzA0X3d0LnBkZg&ntb=1	Minnesota Department of Natural Resources	2016	For the County Geologic and Minnesota Hydrogeology atlases, the Minnesota Department of Natural Resources (DNR) produces water-table elevation and depth to water table maps using data and techniques. The area between the saturated and unsaturated zones is known as the water table, where the water pressure is equivalent to that of the atmosphere. It changes seasonally, annually, and is influenced by cycles of precipitation. Using ArcGIS 10.2.2, a regional water-table map is produced by estimating the elevation of the water table between known data points using the Topo to Raster tool.	Parameter Information
14	Delineation of groundwater potential zones through the integration of remote sensing, geographic information system, and multi criteria decision making technique in the sub Himalayan foothills region, India	https://link.springer.com/article/10.1007/s42108-022-00181-5	Mitra, R., & Roy, D.	2022	Analysis of the groundwater potential zones (GPZs) is crucial given the rising global shortage of groundwater resources. Due to the growth of anthropogenic activity, groundwater is in great demand in the West Bengal region of the sub-Himalayan foothills. Through the integration of remote sensing, geographic information systems (GIS), and multi-criteria decision-making (MCDM) methodologies, GPZs are to be delineated in this work. The resulting groundwater potential zone (GPZ) map shows that the "moderate" GPZ covers the majority of the district (73%), while the "very good" GPZ has the smallest extent and is only present in the south-eastern portion. The results of a micro-level (block-wise) assessment of GPZs showed that Mal, Matiali, and Rajganj prioritized 8.45%, 6.93%, and 4.67% of their respective areas as having "low" groundwater potentiality	GIS-AHP application
15	Delineation of Groundwater Potential Zones in Arid Region of India—A Remote Sensing and GIS Approach	https://link.springer.com/article/10.1007/s11269-012-0038-9	Mukherjee, P., Singh, C. K., & Mukherjee, S.	2012	There is a lack of potable water due to the district's semi-arid climate and infrequent rainfall. Nine themes that regulate the presence of groundwater in any place were built into a groundwater potential zonation map. The findings indicated that 42.8% of the research region had poor potential for groundwater exploration, 13.7% had very bad potential, 27.3% had moderate potential, 11% had high potential, and 5.4% had exceptional potential. A groundwater potential zonation map with nine themes governing the groundwater occurrence in any location and various weights and rank factors was created using the weighted overlay modeling technique. Even though there are more wells available, the data in this area is limited, therefore the map can still be refined.	GIS overlay method
16	Group Aggregation Techniques for Analytic Hierarchy Process and Analytic Network Process: A Comparative Analysis	https://link.springer.com/article/10.1007/s10726-015-9448-4	Ossadnik, W., Schinke, S., & Kaspar, R. H.	2016	Based on how well aggregation methods met requirements for consistency, social choice axioms, and decision context, they were evaluated. Aggregation of individual priorities (AIP) provides the highest level of applicable rationality axiom fulfillment as well as the widest array of applications. loss function approach to group aggregation (LFA) explicitly takes the consistency of pairwise comparison judgments into account. The Group AHP approach is only applicable to small groups and organized problem sets. The most effective aggregation method is AIP.	AHP Method

17	Delineation of groundwater potential zones using remote sensing, GIS, and AHP technique in Tehran–Karaj plain, Iran	https://link.springer.com/article/10.1007/s12665-017-7126-3	Panahi, M. R., Mousavi, S. M., & Rahimzadegan, M.	2017	This study looked at how to create a groundwater potential map in Iran's Tehran-Karaj plain by combining RS, GIS, and AHP approaches. The following seven factors were chosen: slope, drainage density, lineament density, soil, geology, land cover/use, and precipitation. The outcomes were assessed using information from 102 discharge wells. According to the findings, higher groundwater potential zones had higher discharge rates. This methodology is helpful in emerging nations where population growth is more rapid and there is a dearth of hydrogeological data.	GIS-AHP application
18	Delineation of groundwater potential zones for sustainable development and planning using analytical hierarchy process (AHP), and MIF techniques	https://link.springer.com/article/10.1007/s13201-021-01522-1	Pande, C. B., Moharir, K. N., Panneerselvam, B., Singh, S. K., Elbeltagi, A., Pham, Q. B., Varade, A. M., & Rajesh, J.	2021	Using MIF and AHP, this study looked into locating prospective zones in the basin. It identified the 595.82 and 868.86 km2 areas as having a very high likelihood of having groundwater. The results of the cross-validation indicated that AHP is a more accurate method (accuracy = 0.86) for defining possible groundwater zones. MIF is a method that can extract the groundwater potential mapping in the area with a moderate level of precision (accuracy = 0.80). Since four to three large dams and bodies of water are determined to be better conditioning parameters for future groundwater areas, a rapid recovery of the water frame must be stopped immediately.	GIS-AHP application
19	Investigation of groundwater recharge prospect and hydrological response of groundwater augmentation measures in Upper Kosi watershed, Kumaun Himalaya, India	https://www.sciencedirect.com/science/article/abs/pii/S2352801X21001776	Rani, M., Pande, A., Kumar, K., Joshi, H., Rawat, D. S., & Kumar, D.	2022	This study suggested a method for calculating the potential for groundwater recharge in mountainous areas. To combine hydrological parameters and offer a spatial distribution of feasible sites for groundwater intervention, remote sensing techniques and GIS tools were used. The proposed technique increased discharge at the testing site, according to the results. The validity of the suggested places has to be confirmed by further investigation. The findings of this study are important in helping to manage groundwater resources broadly and the process of recharging them.	GIS overlay method
20	ArcNLET: A GIS-based software to simulate groundwater nitrate load from septic systems to surface water bodies	https://www.sciencedirect.com/science/article/pii/S0098300412003421#:~:text=ArcNLET%20functions%20as%20a%20screening%20model%20embedded%20within,surface%20water%20bodies%20from%20OWTS%20at%20neighborhood%20scales.	Rios, J. F., Ye, M., Wang, L., Lee, P. Z., Davis, H., & Hicks, R.	2012	Nitrates can be released by onsite wastewater treatment systems (OWTS) into groundwater and surface water, raising safety issues. The ArcGIS-based Nitrogen Load Estimation Toolkit (ArcNLET) program was created to lower the expenses associated with data gathering and preparation. It assesses long-term nitrate loads from groundwater to surface water bodies and simplifies nitrate movement in groundwater. Groundwater flow, nitrate transport and fate, and load estimation are three of the software's sub-models. While the transport model predicts the distribution of nitrate in groundwater, the groundwater flow model uses a topography map to produce a steady-state approximation of the water table. The estimations from ArcNLET are appropriate for screening-level analysis.	Parameter Information
21	The analytic hierarchy process—what it is and how it is used	https://www.sciencedirect.com/science/article/pii/0270025587904738	Saaty, R.W.	1987	The Analytic Hierarchy Process is a method of measurement with ratio scales and illustrates it with two examples. Its axioms and theoretical underpinnings are discussed, with special emphasis on departure from consistency and the use of absolute and relative measurement.	AHP Method
22	The Modern Science of Multicriteria Decision Making and Its Practical Applications: The AHP/ANP Approach	https://pubsonline.informs.org/doi/abs/10.1287/opre.2013.1197	Saaty, T. L.	2013	Mathematical methods for assessing physical and intangible aspects, particularly when used to decision making, include the Analytic Hierarchy Process (AHP) and its generalization to dependence and feedback, the Analytic Network Process (ANP). Even if one could demonstrate with an example how all three approaches result in the same ranking of alternatives in some circumstances, this would not demonstrate the method's value. They must be evaluated in accordance with the standards of mathematical correctness. A few concerns addressed were rank reversal (illegitimate changes in the ranks of the alternatives), inconsistent judgements, preserving ranks from irrelevant alternatives, trying to change the fundamental scale and whether the pairwise comparisons axioms are behavorial and spontaneous	AHP Method
23	How to make a decision: The Analytic Hierarchy Process	https://www.sciencedirect.com/science/article/abs/pii/037722179090057I	Saaty, T. L.	1990	The relative ratio scales of measurement produced by the AHP can be normalized to yield relative scale measurements. But when different weights are normalized and composed on the same standard scale according to many criteria, the results are illogical. The weights must be built with consideration for all criteria before being normalized for AHP use in order to evaluate the results of manipulations based on combining various data from a standard scale.	AHP Method
24	Decision-making with the AHP: Why is the principal eigenvector necessary	https://www.sciencedirect.com/science/article/abs/pii/S0377221702002278	Saaty, T. L.	2003	The study demonstrated that, provided that the inconsistency is less than or equal to a desired value, the principal eigenvector is required for representing the priorities associated with a positive reciprocal pairwise comparison matrix if inconsistency is allowed in that matrix. The study also discussed three methods for enhancing judgment consistency and changing an inconsistent matrix into a nearly consistent matrix, two of which were presented.	AHP Method
25	Groundwater potential zone mapping using analytical hierarchy process (AHP) and GIS for Kancheepuram District, Tamilnadu, India	https://link.springer.com/article/10.1007/s40808-020-00744-7	Saranya, T., & Saravanan, S.	2020	For the Kancheepuram district, the ground water potential zone was identified using a geographic information system. Results were divided into five classifications, with Meenambakkam, Sriperambadur, Cheyyar, and a few spots along the river's course falling into the category of extremely high potential. While Kovalam and Uthiramerur had a moderate potential, Vayalur, Thiruporur, and Mathuranthagam had a high potential. The key variables influencing recharge in the research area were found to be rainfall, drainage density, and geomorphology. The groundwater table can be raised and overexploitation avoided by implementing artificial recharge techniques and participative approaches.	GIS-AHP application
26	Potential groundwater recharge zones within New Zealand	https://www.sciencedirect.com/science/article/pii/S1674987118301488	Singh, S. K., Zeddies, M., Shankar, U., & Griffiths	2019	In order to map GWRpot zones around New Zealand and categorize them into 5 descriptive types, GIS techniques were applied. According to the findings, low raised areas and flat terrain with Quaternary deposits have high potential, while urban settlements and mountains with steep slopes have low potential.	GIS-AHP application
27	Assessing the accuracy of GIS-based Multi-Criteria Decision Analysis approaches for mapping groundwater potential	https://www.sciencedirect.com/science/article/abs/pii/S1470160X18302255	Singh, S. K., Zeddies, M., Shankar, U., & Griffiths, G. A.	2018	The weights of themes and their characteristics were allocated in the AHP-based MCDA approach in accordance with Saaty's AHP theory, whereas the index value of the features was determined in the Catastrophe theory-based MCDA approach. Finally, a novel methodology was used to validate the outcomes of these GIS-based MCDA methodologies.	GIS-AHP application
28	Soil Survey Manual	https://www.nrcs.usda.gov/resources/guides-and-instructions/soil-survey-manual	Soil Survey Divison Staff	2017	Document showing interpretive soil properties and limitations for Septic Tank Absorption Suitability, with corresponding values.	Parameter Information
29	Application for Construction Permit	https://www.flrules.org/gateway/reference.asp?No=Ref-14359	State of Florida, Department of Environmental Protection	Date accessed: 6/26/2023	Application document for construction permitting.	OSTDS specific
30	Standards for Onsite Sewage Treatment and Disposal Systems	https://www.floridahealth.gov/environmental-health/onsite-sewage/forms-publications/_documents/64e-6.pdf	Department of Health	2018	CHAPTER 64E-6, FLORIDA ADMINISTRATIVE CODE STANDARDS FOR ONSITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS	OSTDS specific
31	Custom Soil Resource Report for St. Lucie County, Florida	https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx	United States Department of Agriculture	Date accessed: 6/19/2023	Soil surveys include details on the location, characteristics, and limitations of soils. In addition to describing soil profiles, which are the organic layers of a soil, they also take note of slopes, drainage patterns, crops, native plants, and bedrock.	Parameter Information
32	Part 630 Hydrology National Engineering Handbook- Chapter 7 Hydrologic Soil Groups	https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=22526.wba	United States Department of Agriculture	2007	This chapter contains the official definitions of the various hydrologic soil groups. The National Soil Survey Handbook (NSSH) references and refers users to NEH630.07 as the official hydrologic soil group (HSG) reference.	Parameter Information

33	Septic Tank Absorption Fields (FL)—St. Lucie County, Florida	https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx	United States Department of Agriculture	Date accessed: 06/22/2023	Standard Trench Drainfield Systems are subsurface systems of distribution lines that distribute effluent from a septic tank into the natural soil. The distribution lines are at a minimum of 12 inches. Only the soil between depths of 0 and 60 inches is considered in making the ratings. Soil properties and site features considered are those that affect the absorption of the effluent, those that affect the construction and maintenance of the system, and those that may affect public health.	OSTDS specific
34	Synthesizing Detailed Expert Guidance on FDEP's Septic Vulnerability Assessment Model and Pilot-Testing Recommended Improvements-Workshop Report	Source: FDEP OEAT	University of Florida, Center for Coastal Solutions, University of Florida Water Institute, University of Florida Institute for Food and Agricultural Sciences, and Florida State University	2022	The workshop described in this report was a component of a larger project funded by the Florida Department of Environmental Protection that concentrated on gathering and synthesizing expert input on a device (such as the SAS dashboard) for evaluating the potential susceptibility of waterbodies to on-site sewage treatment and pollution in Florida from OSTDS systems. The project's goal is to provide recommendations on how to develop the instrument, assess its performance, and suggest potential long-term modifications to the tool that has been subject to expert review and literature research.	Parameter Information
35	Synthesizing Detailed Expert Guidance on FDEP's Septic Vulnerability Assessment Model and Pilot-Testing Recommended Improvements-Report of Preliminary Analyses	Source: FDEP OEAT	University of Florida, Center for Coastal Solutions, University of Florida Water Institute, University of Florida Institute for Food and Agricultural Sciences, and Florida State University	2022	The creation of a tool to evaluate the susceptibility of waterbodies to OSTDS pollution is one of three tasks being supported by the Florida Department of Environmental Protection (DEP). Based on OSTDS pollutant load, transit, and the possibility that OSTDS-derived pollution may damage sensitive waterways, the application employs an interactive map and a dashboard. The project attempts to develop the tool, assess performance, and suggest further upgrades.	Parameter Information
36	ArcNLET: An ArcGIS-Based Nitrate Load Estimation Toolkit	https://www.bing.com/ck/a?!&&p=837699f4e3483512JmltdHM9MTY4NzQ3ODQwMCZpZ3VpZD0zMmFiYzllOS1jMWNjLTYzNDQtMWUzNy1kYjIzYzBlZDYyY2UmaW5zaWQ9NTIxNw&ptn=3&hsh=3&fclid=32abc9e9-c1cc-6344-1e37-db23c0ed62ce&psq=ArcNLET%3a+An+ArcGIS-Based+Nitrate+Load+Estimation+Toolkit&u=a1aHR0cHM6Ly9hdG1vcy5lb2FzLmZzdS5lZHUvfm15ZS9BcmNOTEVUL2FwcGxpY2F0aW9uX21hbnVhbC5wZGY&ntb=1	Wang, L., Ye, M.,Rio,s J. F., Lee, P.	2019	The usage of ArcNLET (ArcGIS-Based Nitrate Load Estimation Toolkit) for simulations of nitrate fate and transport in septic systems is covered in this document. The fundamental model and algorithmic implementation are described in detail, and it includes real-world applications in the neighborhoods of Eggleston Heights and Julington Creek. Instructions for installation and use are provided in the user's manual.	Parameter Information

Appendix 2

List of attendees identified for the workshop held on June 5th, 2023.

People who attended or led the workshop on June 5th, 2023.

Name	Representation
Baker, Alan*	DEP
Bubel, Ansel	DEP
Campbell, Lauren*	DEP
Chen, Gang*	FSU (Academia)
Crotty, Wayne	Crotty Services Inc. (Industry)
Danyuk, Julia	DEP
Davis, Sara C.	DEP
Gao, Xueqing*	DEP
Groover, Roxanne*	FOWA
Guerron Orejuela, Edgar	USF (Academia)
Hankinson, Samuel*	DEP
Homann, Moira	DEP
Ingram, Brian*	St. Lucie County
Landry, Shawn	USF (Academia)
Means, Harley*	DEP
Morris, Kristine P.	DEP
Okonkwo, Moses	DEP
Rains, Kai*	USF (Academia)
Rains, Mark*	DEP/USF
Roeder, Eb*	DEP
Turner, Diana M.	DEP
Weaver, Kenneth	DEP
Ye, Ming*	FSU (Academia)

- * These subject matter experts returned completed pairwise comparisons to the OEAT-USF team

Appendix 3

Workshop agenda held on June 5th, 2023.

AT015 OSTDS SME Workshop Agenda

- Welcome
- Participant introductions (10 minutes)
- Background and general project overview (10 minutes)
- Introduction to Analytic Hierarchy Process (AHP) (1 hr)
    - AHP overview
    - AHP in practice: development of a geospatial tool using AHP and related confidence metrics to support groundwater resource management
    - Q&A
- Break (15 min)
- AHP activity overview and directions (30 min)
    - Introduction and demonstration of pairwise comparison exercise
    - Process re-cap and future steps
    - Open discussion and Q&A
- Break (5 min)
- SME AHP activity (1 hr)
    - Independent pairwise comparison of parameters by SMEs with live support by USF
    - Submission of AHP activity by workshop participants

Appendix 4

Slides presented during workshop held on June 5th, 2023.

Development of a Septic-to-Sewer Conversion Prioritization Tool Using Analytic Hierarchy Process (AHP)

Ecohydrology Research Group - University of South Florida

Edgar Guerron-Orejuela, PhD Candidate

AT015 OSTDS SME Workshop Agenda

- Welcome and participant introductions (10 minutes)
- Background and general project overview (10 minutes)
- Introduction to Analytic Hierarchy Process (AHP) (1 hr)
  - AHP overview
  - AHP in practice: development of a geospatial tool using AHP and related confidence metrics to support groundwater resource management
  - Q&A
- Break (15 min)
- AHP activity overview and directions (30 min)
  - Introduction and demonstration of pairwise comparison exercise
  - Process re-cap and future steps
  - Open discussion and Q&A
- Break (5 min)
- SME AHP activity (1 hr)
  - Independent pairwise comparison of parameters by SMEs with live support by USF
  - Submission of AHP activity by workshop participants

Why are we here?

Richard Graulich/The Palm Beach Post via AP)
https://www.dailycommercial.com/story/news/state/2017/05/04/floridas-building-boom-threatens-wildlife-rich-indian-river-lagoon/21208769007/

Greg Lovett/ The Palm Beach Post via AP)
https://www.jacksonville.com/story/news/2017/05/04/over-2900-species-look-florida-s-indian-river-lagoon/15753633007/

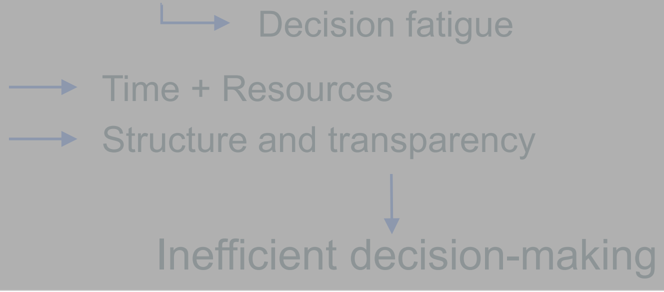
Our goal is to develop a model framework that, once implemented in GIS, will map locations by the degree of environmental risk posed by OSTDS.

Based on physical parameters that provide important information for determining nutrient movement from OSTDS to nearby water bodies.

- Choose parameters
- Weight parameters

- Senior executives spend nearly 40% of their time making decisions

McKinsey & Company, 2023



→ Decision fatigue

→ Time + Resources

→ Structure and transparency

↓

Inefficient decision-making

Challenges

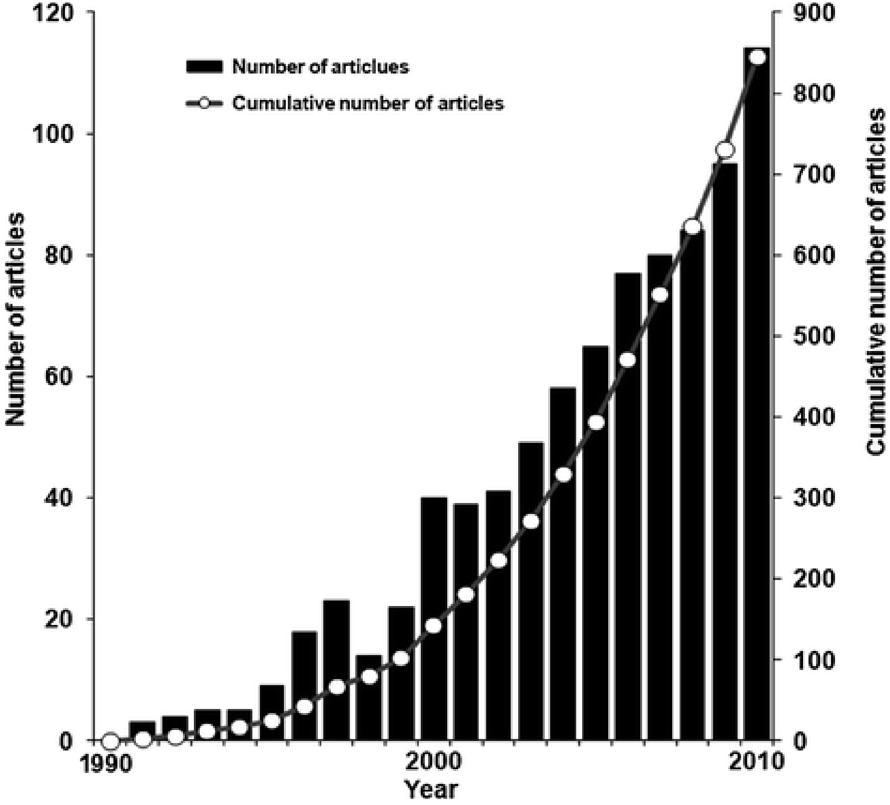
- Too much data
- No data
- Data accessibility
- Structured and unstructured data
- Differences in spatial and temporal scale

↓

MULTI-CRITERIA DECISION ANALYSIS (MCDA)

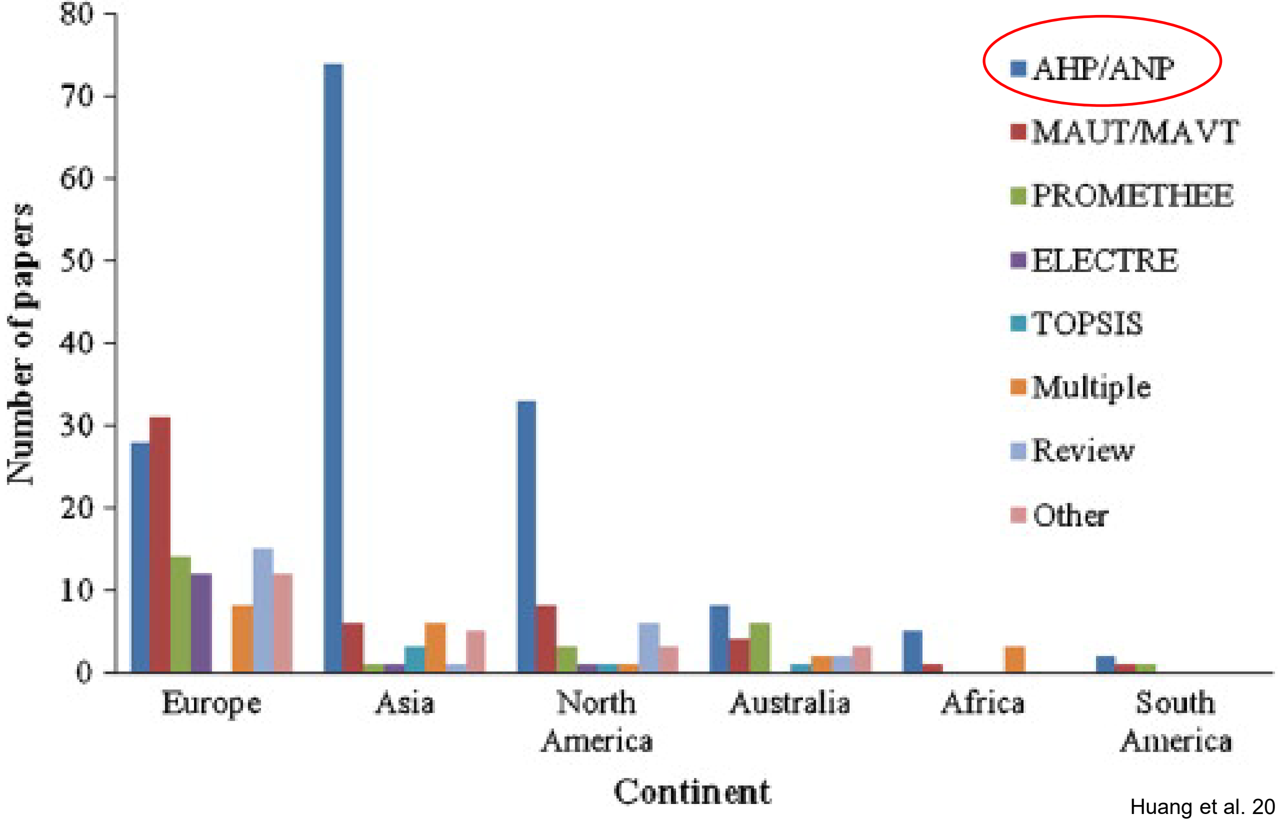
UNIVERSITY of
SOUTH FLORIDA

MCDA and GIS



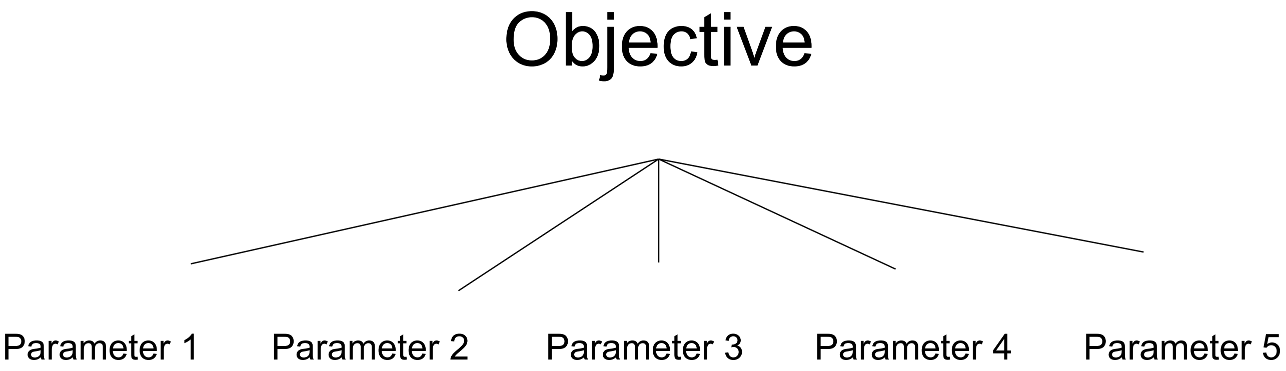
Malczewski & Rinner 2015 (see also Cegan et al. 2017)

MCDA methods



Huang et al. 2011 (see also Cegan et al. 2017)

Analytic Hierarchy Process



Objective

Parameter 1

Parameter 2

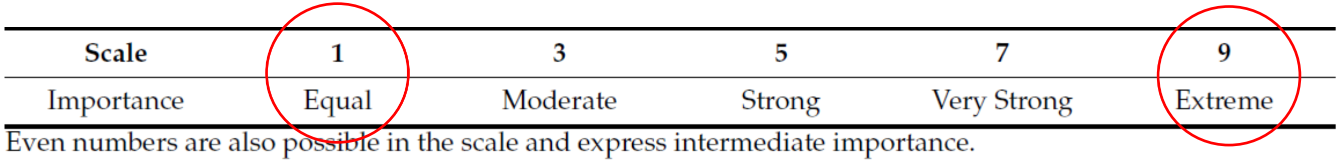
Parameter 3

Parameter 4

Parameter 5

What question are we trying to answer?

What parameters will help us answer our question?

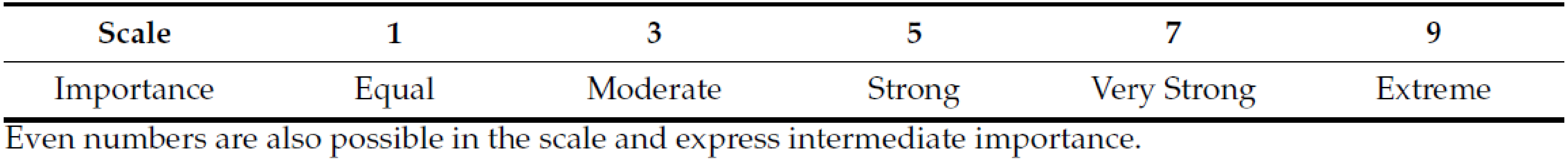


Scale	1	3	5	7	9
Importance	Equal	Moderate	Strong	Very Strong	Extreme

Even numbers are also possible in the scale and express intermediate importance.

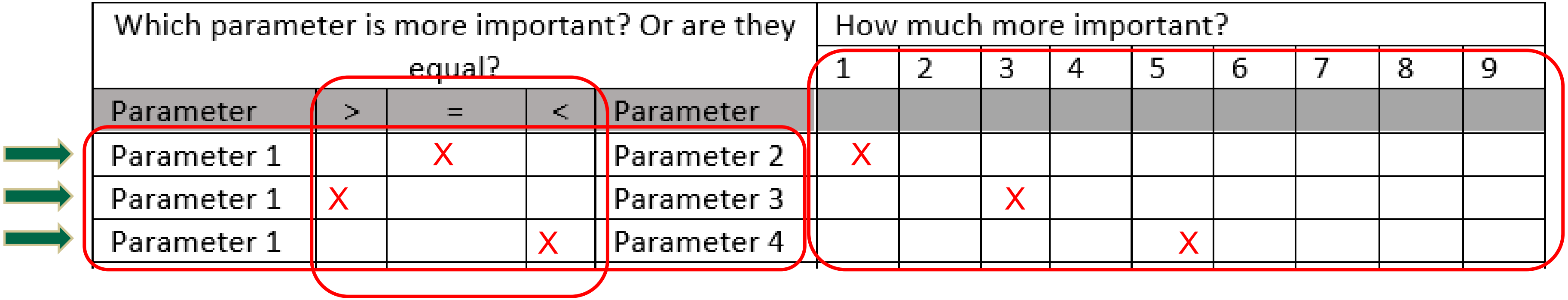
Determine which carry more weight to answer our question?

Pairwise Comparison of Parameters



Scale	1	3	5	7	9
Importance	Equal	Moderate	Strong	Very Strong	Extreme

Even numbers are also possible in the scale and express intermediate importance.



Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Parameter 1		X		Parameter 2	X								
Parameter 1	X			Parameter 3			X						
Parameter 1			X	Parameter 4					X				

	Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5
Parameter 1	**1**	1	3	1/5	7
Parameter 2	1	**1**	1/2	3	1/3
Parameter 3	1/3	2	**1**	1/3	2
Parameter 4	5	1/3	3	**1**	3
Parameter 5	1/7	3	1/2	1/3	**1**

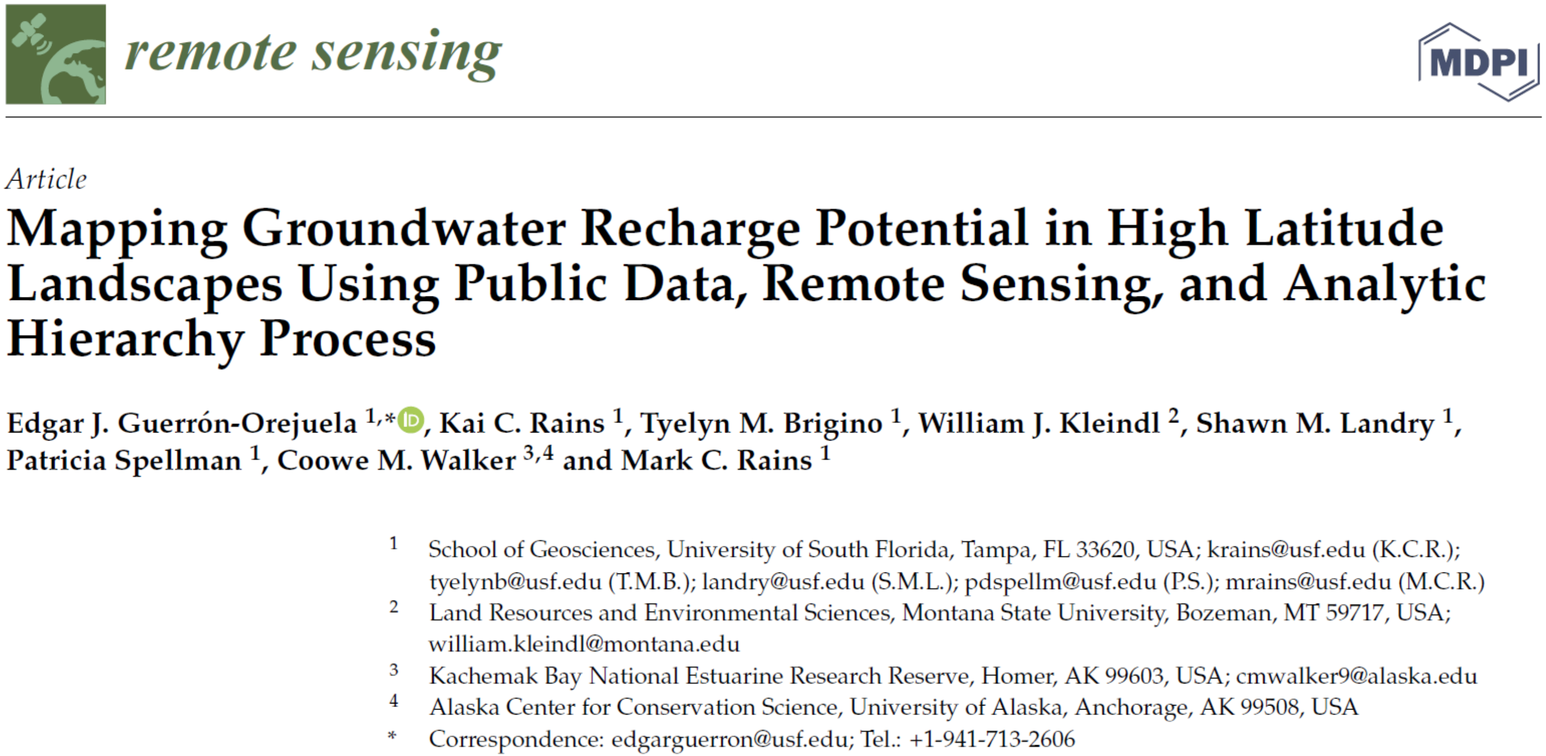
Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Parameter 1		X		Parameter 2	X								
Parameter 1	X			Parameter 3			X						
Parameter 1			X	Parameter 4					X				

	Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5
Parameter 1	1	3	5 3		
Parameter 2		1	5		
Parameter 3			1		
Parameter 4				1	
Parameter 5					1

Scale	1	3	5	7	9
Importance	Equal	Moderate	Strong	Very Strong	Extreme

Even numbers are also possible in the scale and express intermediate importance.

Analytic Hierarchy Process Example



remote sensing
MDPI

Article

Mapping Groundwater Recharge Potential in High Latitude Landscapes Using Public Data, Remote Sensing, and Analytic Hierarchy Process

Edgar J. Guerrón-Orejuela [1,*], Kai C. Rains [1], Tyelyn M. Brigino [1], William J. Kleindl [2], Shawn M. Landry [1], Patricia Spellman [1], Coowe M. Walker [3,4] and Mark C. Rains [1]

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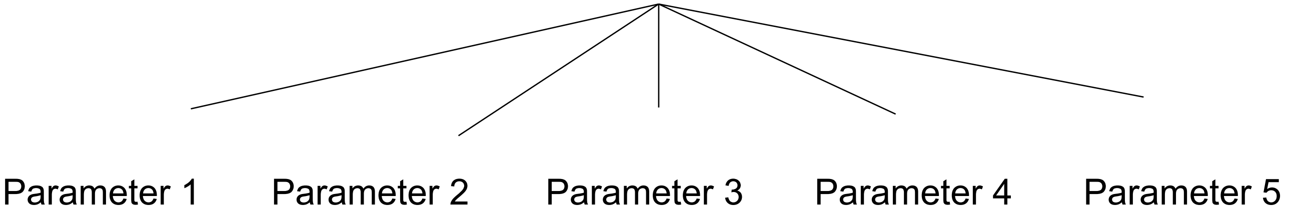
[2] Land Resources and Environmental Sciences, Montana State University, Bozeman, MT 59717, USA; william.kleindl@montana.edu
[3] Kachemak Bay National Estuarine Research Reserve, Homer, AK 99603, USA; cmwalker9@alaska.edu
[4] Alaska Center for Conservation Science, University of Alaska, Anchorage, AK 99508, USA
* Correspondence: edgarguerron@usf.edu; Tel.: +1-941-713-2606

Objective

Map groundwater recharge potential areas



Parameter 1

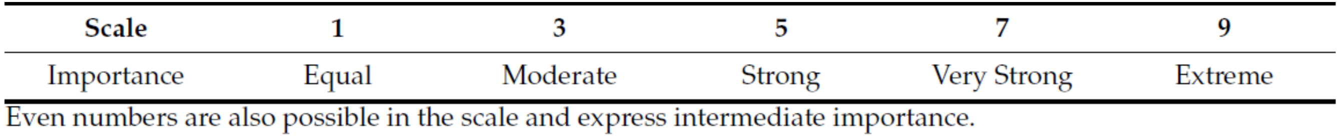
Parameter 2

Parameter 3

Parameter 4

Parameter 5

What parameters will help us answer our question?

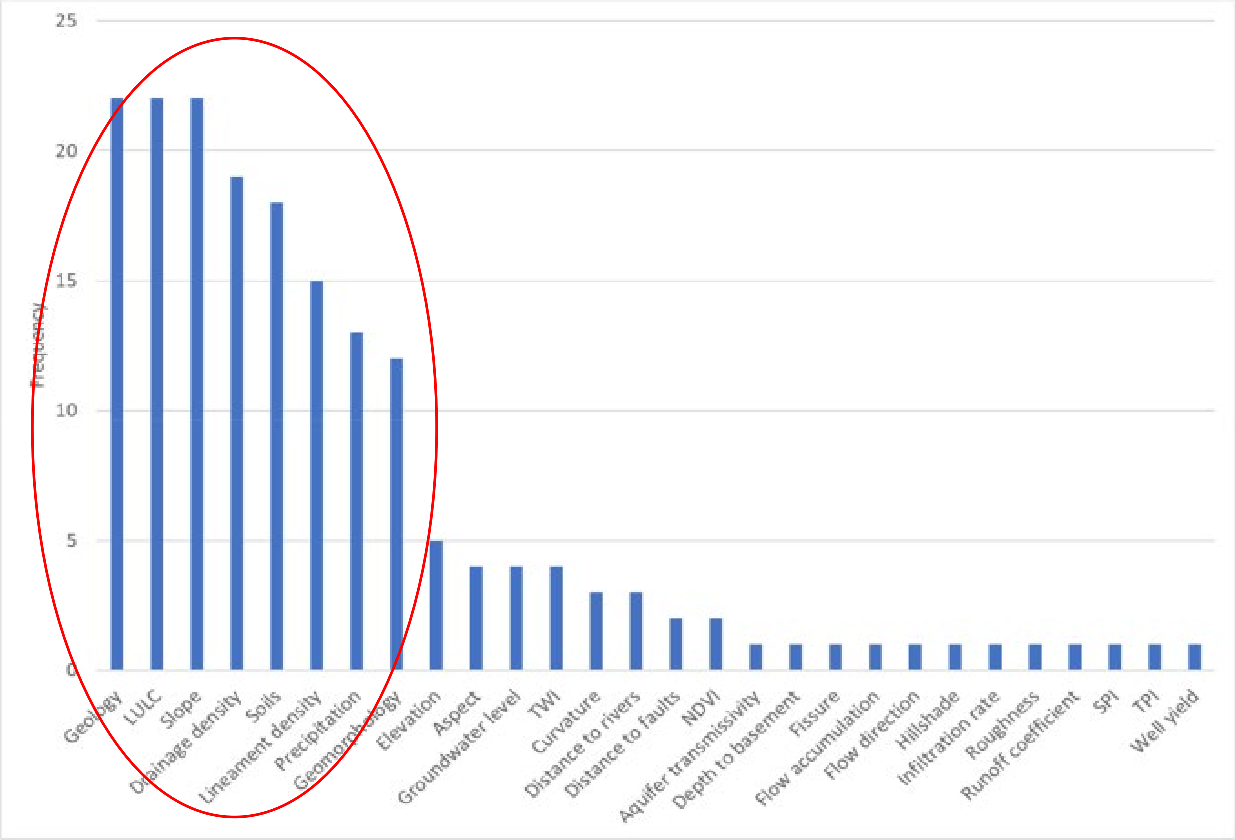


Scale	1	3	5	7	9
Importance	Equal	Moderate	Strong	Very Strong	Extreme

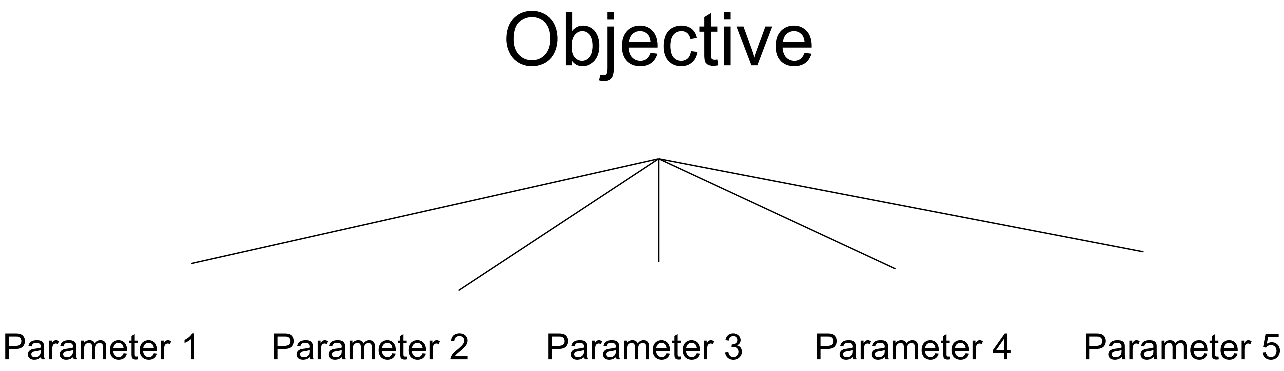
Even numbers are also possible in the scale and express intermediate importance.

From these parameters which carry more weight in the outcome?

Spatial dataset selection process



Guerron-Orejuela et al. 2023

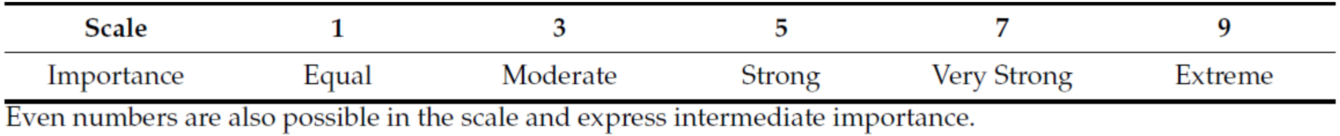


Objective

Parameter 1 Parameter 2 Parameter 3 Parameter 4 Parameter 5

Map groundwater recharge potential areas

- Precipitation
- Geology
- Soil texture
- Slope
- Drainage density
- Land cover



Scale	**1**	**3**	**5**	**7**	**9**
Importance	Equal	Moderate	Strong	Very Strong	Extreme

Even numbers are also possible in the scale and express intermediate importance.

From these parameters which carry more weight in the outcome?

Pairwise Comparison Matrix

Parameters	Precipitation	Geology	Soil Texture	Slope	Drainage Density	Land Cover
Precipitation	**1**	1	1/2	1/2	3	1/2
Geology	1	**1**	1/2	1/3	3	1/2
Soil Texture	2	2	**1**	1/3	5	1/2
Slope	2	3	3	**1**	5	2
Drainage Density	1/3	1/3	1/5	1/5	**1**	1/5
Land Cover	2	2	2	1/2	5	**1**

Standardized Comparison Matrix

Parameters	Precipitation	Geology	Soil Texture	Slope	Drainage Density	Land Cover
Precipitation	0.12	0.11	0.07	0.17	0.14	0.11
Geology	0.12	0.11	0.07	0.12	0.14	0.11
Soil Texture	0.24	0.21	0.14	0.12	0.23	0.11
Slope	0.24	0.32	0.42	0.35	0.23	0.43
Drainage Density	0.04	0.04	0.03	0.07	0.05	0.04
Land Cover	0.24	0.21	0.28	0.17	0.23	0.21
Sum	1	1	1	1	1	1

Parameters	Eigenvector (%)
Precipitation	12
Geology	11
Soil Texture	18
Slope	33
Drainage Density	4
Land Cover	22
Sum	100

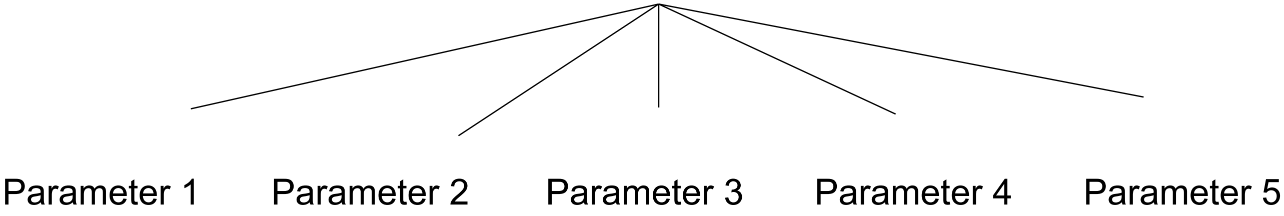
Principal eigenvalue = 6.22

Consistency Index = 0.04

Consistency Ratio = 0.035

Random Consistency Index = 1.24

Objective


Parameter 1 Parameter 2 Parameter 3 Parameter 4 Parameter 5

Scale	1	3	5	7	9
Importance	Equal	Moderate	Strong	Very Strong	Extreme

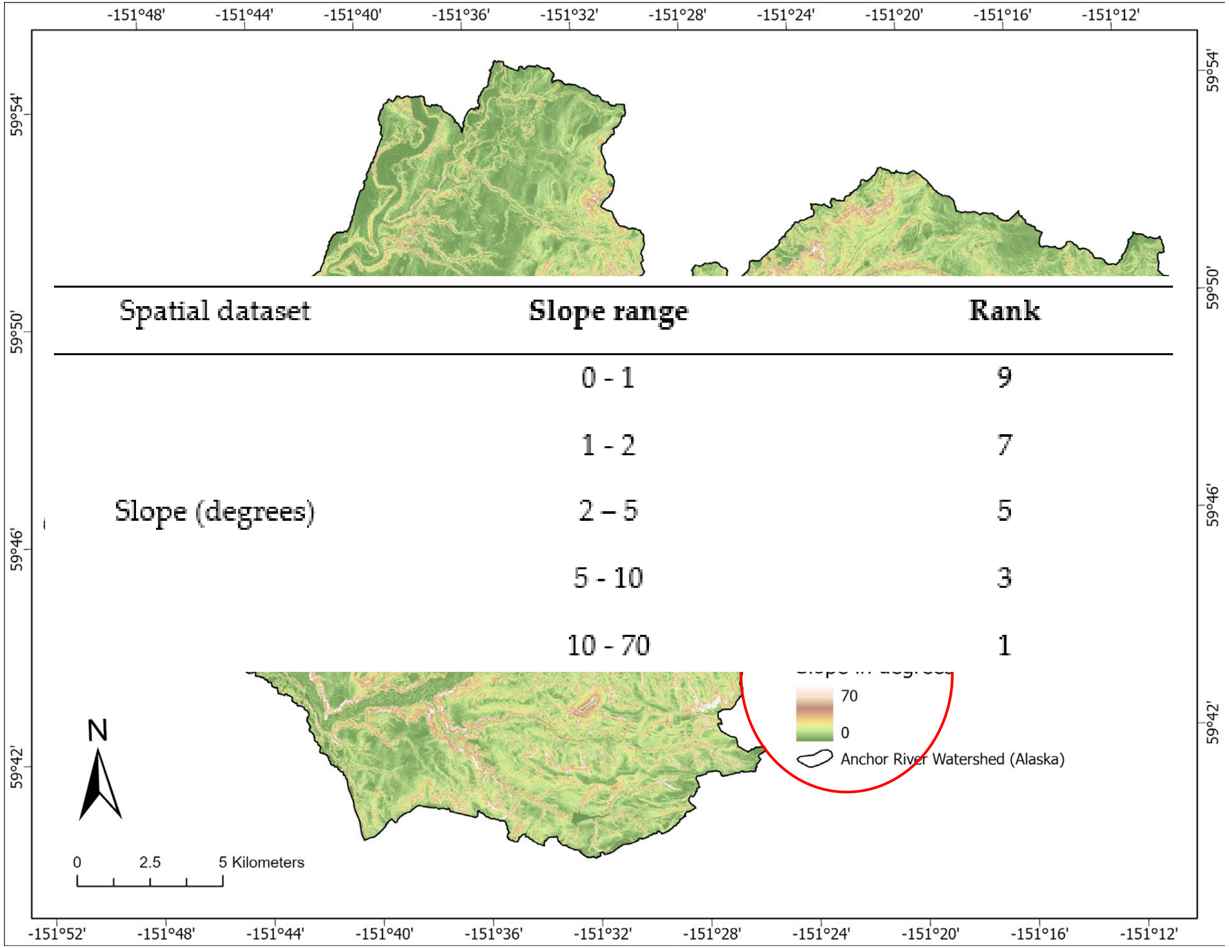
Even numbers are also possible in the scale and express intermediate importance.

Map groundwater recharge potential areas

- Precipitation
- Geology
- Soil texture
- Slope
- Drainage density
- Land cover

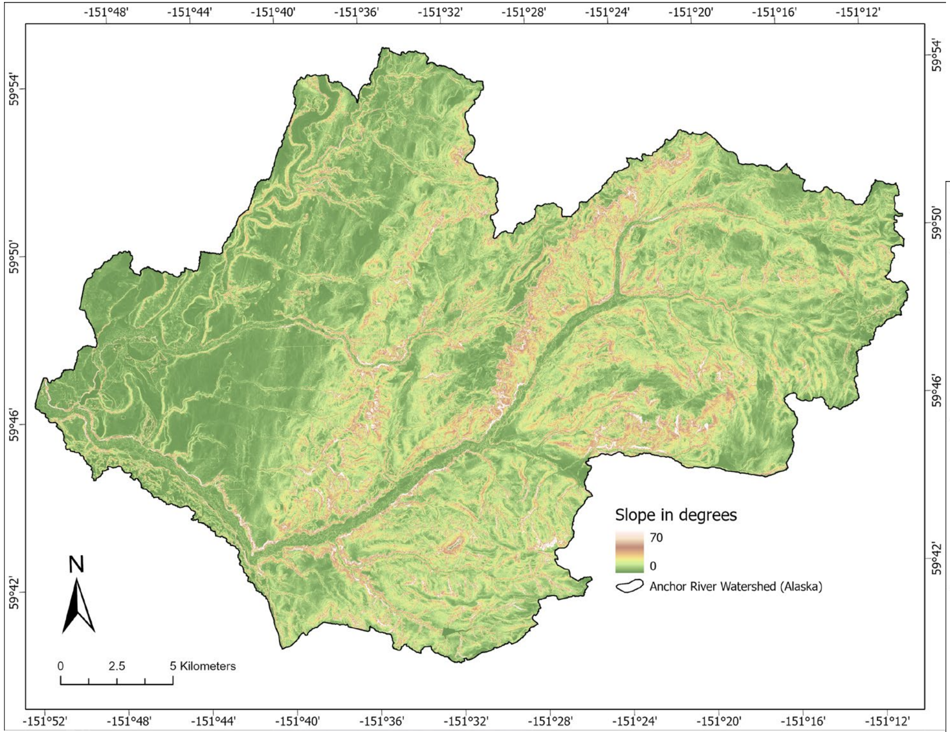
- Precipitation (12%)
- Geology (11%)
- Soil texture (18%)
- Slope (33%)
- Drainage density (4%)
- Land cover (22%)

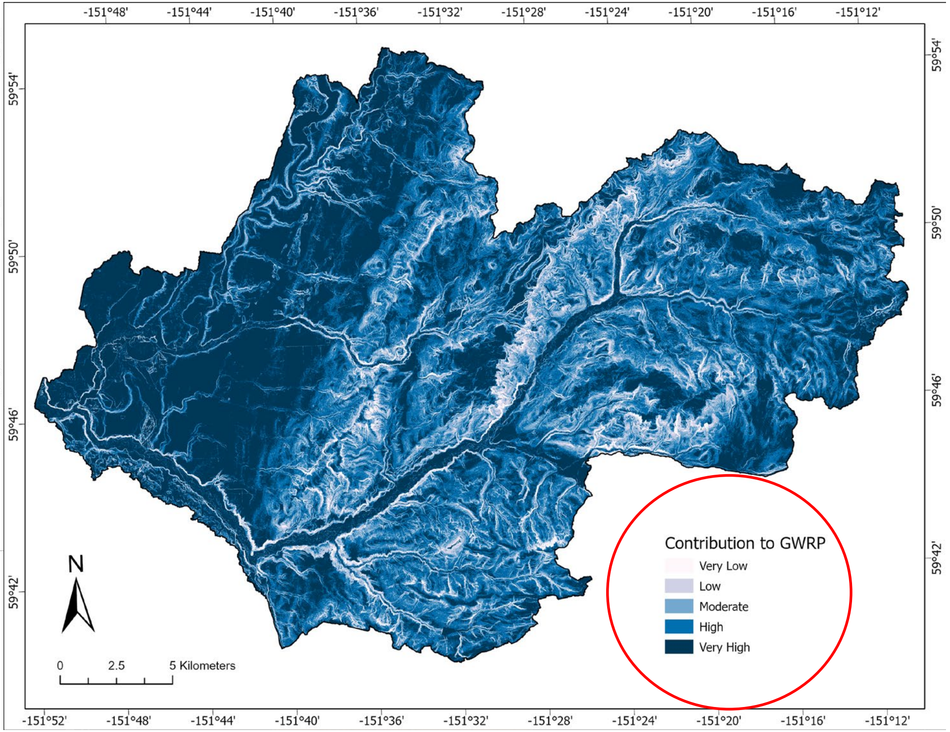
Final Product demonstration



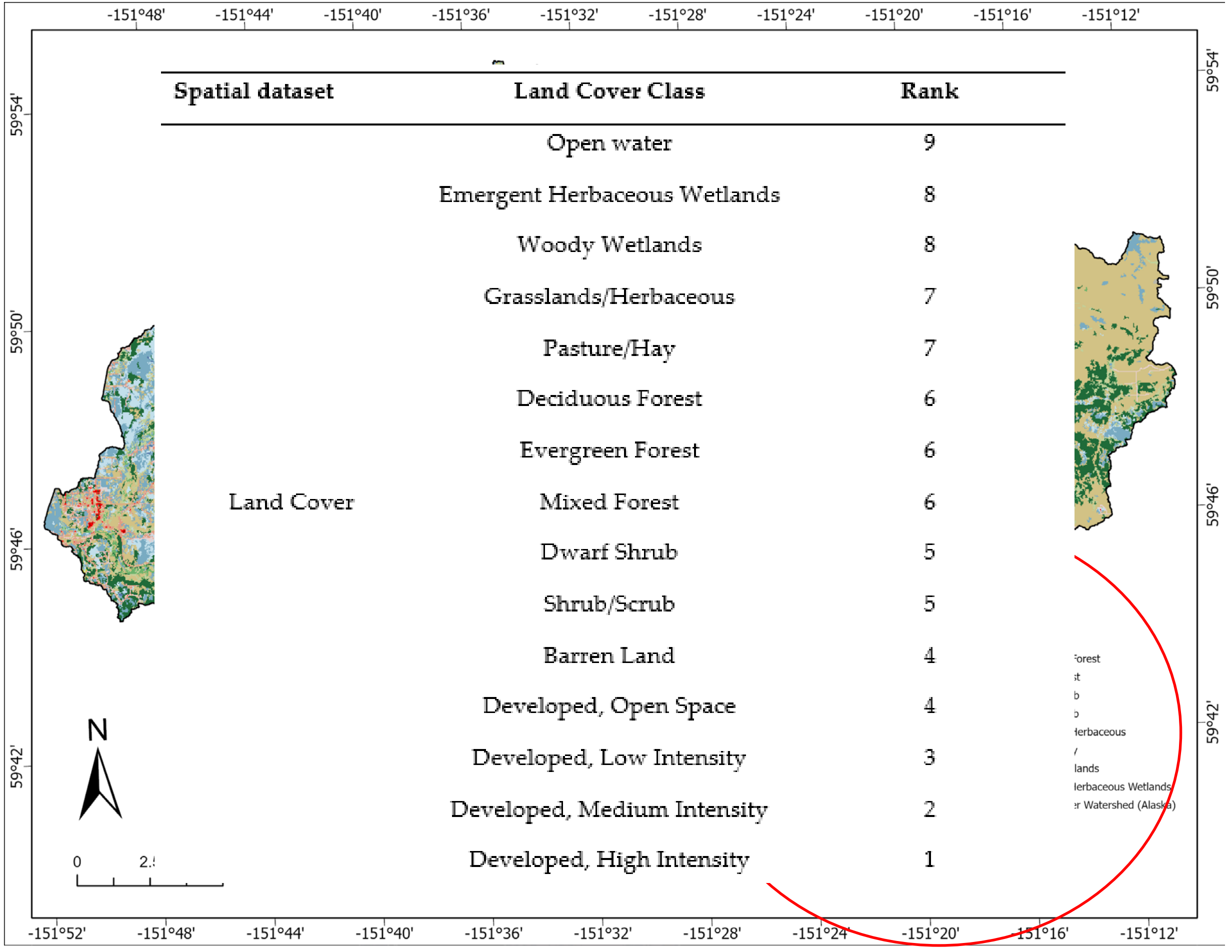
Spatial dataset	Slope range	Rank
Slope (degrees)	0 - 1	9
	1 - 2	7
	2 – 5	5
	5 - 10	3
	10 - 70	1

Guerron-Orejuela et al. 2023



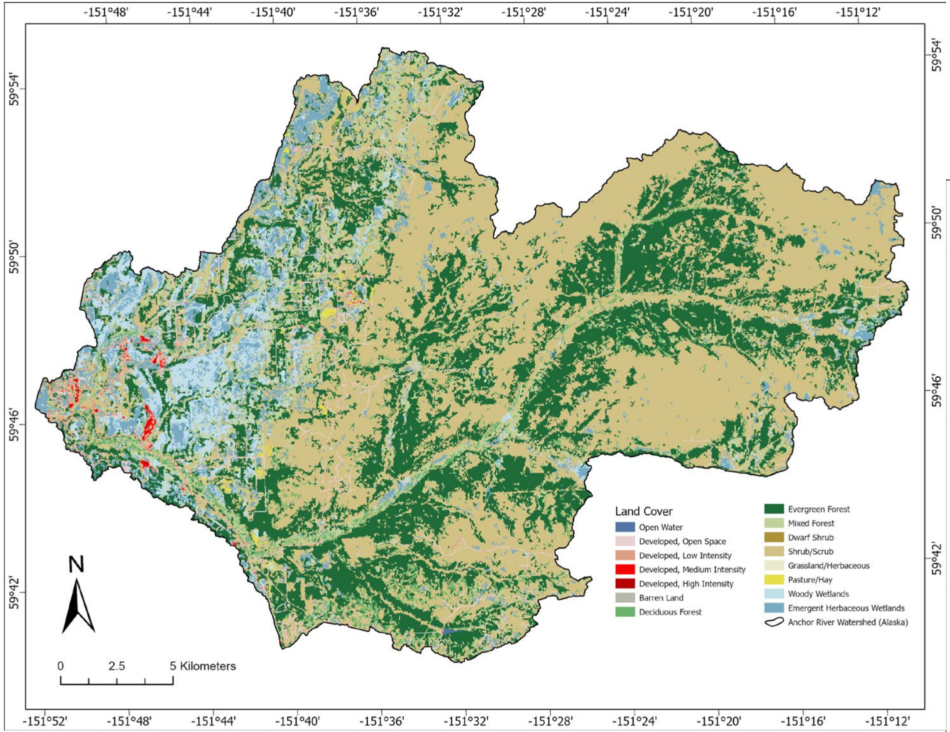


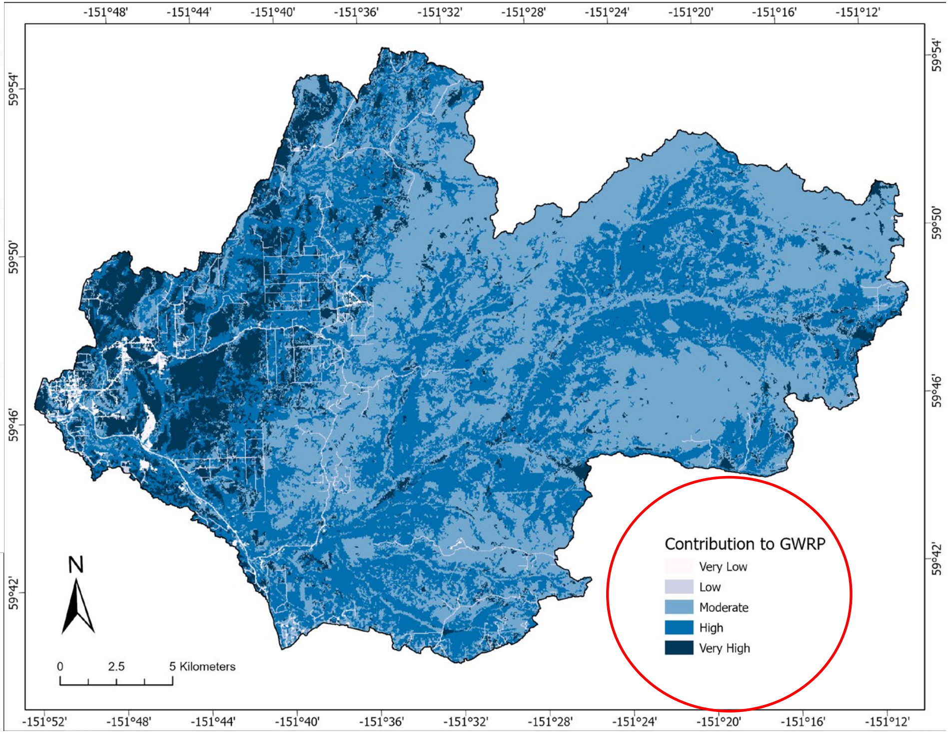
Guerron-Orejuela et al. 2023



Spatial dataset	Land Cover Class	Rank
Land Cover	Open water	9
	Emergent Herbaceous Wetlands	8
	Woody Wetlands	8
	Grasslands/Herbaceous	7
	Pasture/Hay	7
	Deciduous Forest	6
	Evergreen Forest	6
	Mixed Forest	6
	Dwarf Shrub	5
	Shrub/Scrub	5
	Barren Land	4
	Developed, Open Space	4
	Developed, Low Intensity	3
	Developed, Medium Intensity	2
	Developed, High Intensity	1

Guerron-Orejuela et al. 2023



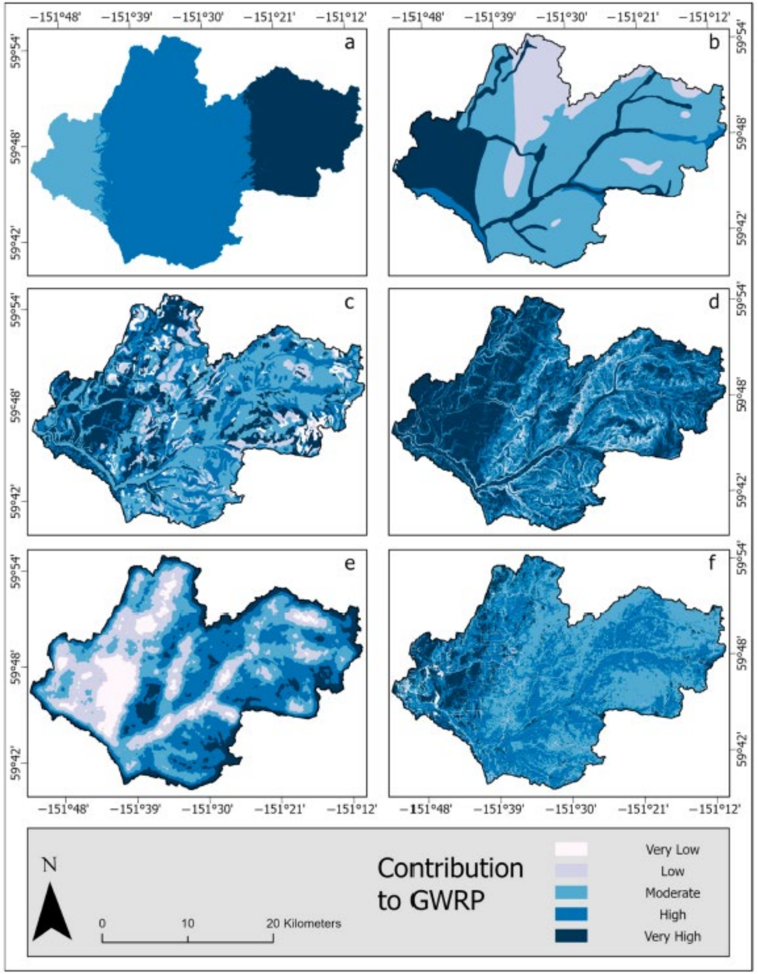


Guerron-Orejuela et al. 2023

12%

18%

4%

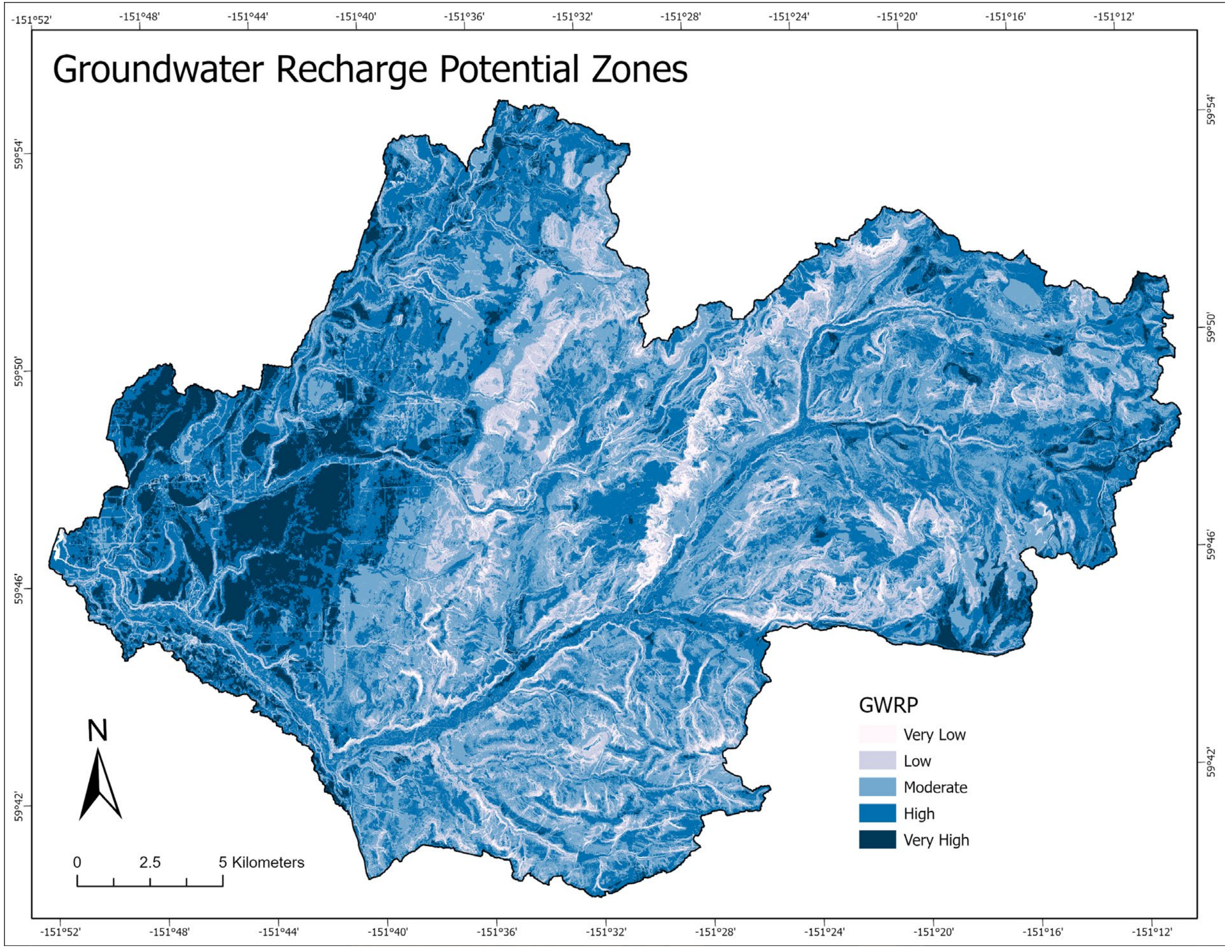


11%

33%

22%

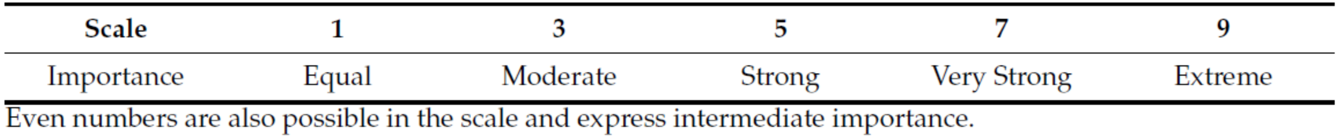
Guerron-Orejuela et al. 2023



Model accuracy = 87%

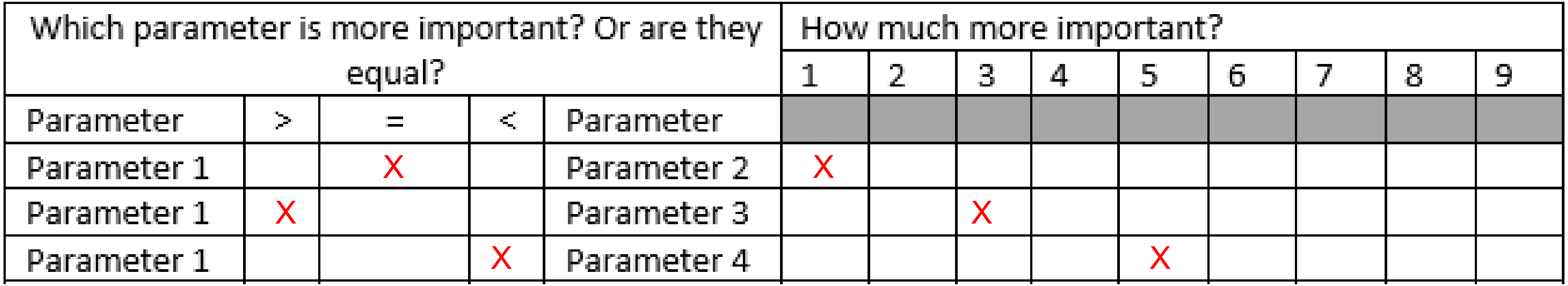
Guerron-Orejuela et al. 2023

Pairwise Comparison of Parameters



Scale	**1**	**3**	**5**	**7**	**9**
Importance	Equal	Moderate	Strong	Very Strong	Extreme

Even numbers are also possible in the scale and express intermediate importance.



Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter	▨	▨	▨	▨	▨	▨	▨	▨	▨
Parameter 1		X		Parameter 2	X								
Parameter 1	X			Parameter 3			X						
Parameter 1			X	Parameter 4					X				

Break (15 min)

Parameter Identification (CCS –SAS Survey list)

Proximity to water

1. Depth to water
2. Depth to karst
3. Distance to natural surface waterbodies
4. Drainfield depth to seasonal high-water table
5. Potential for flooding
6. Within a sensitive area (OFS, PFA, BMAP)

Septic system & Population

7. Acres
8. OSTDS age
9. OSTDS density
10. Onsite system type
11. Landuse
12. Parcel density
13. Persons/Household (census)
14. 2018 Population
15. Wastewater service type

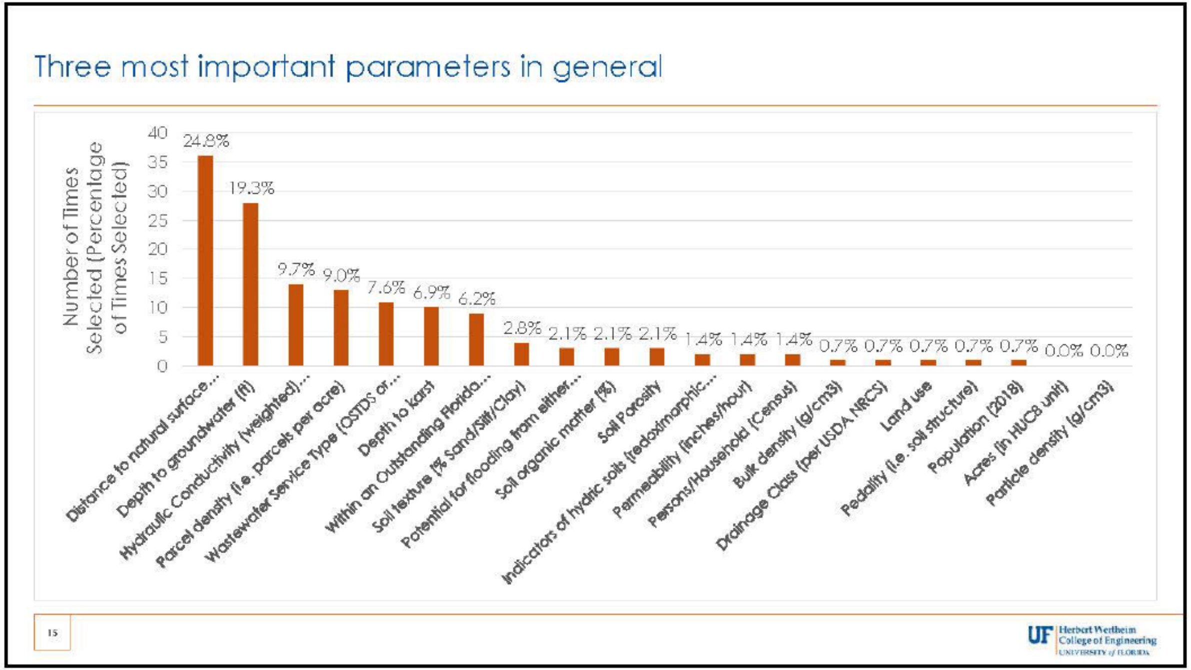
Soil Properties

16. Bulk density (g/cm3)
17. Indicators of Hydric soils
18. Particle density (g/cm3)
19. Pedality (i.e. soil structure)
20. Soil organic matter
21. Soil porosity
22. Soil texture

Water movement through soil

23. Drainage class
24. Hydraulic Conductivity (weighted) (mm/s)
25. Permeability (inches/hr)

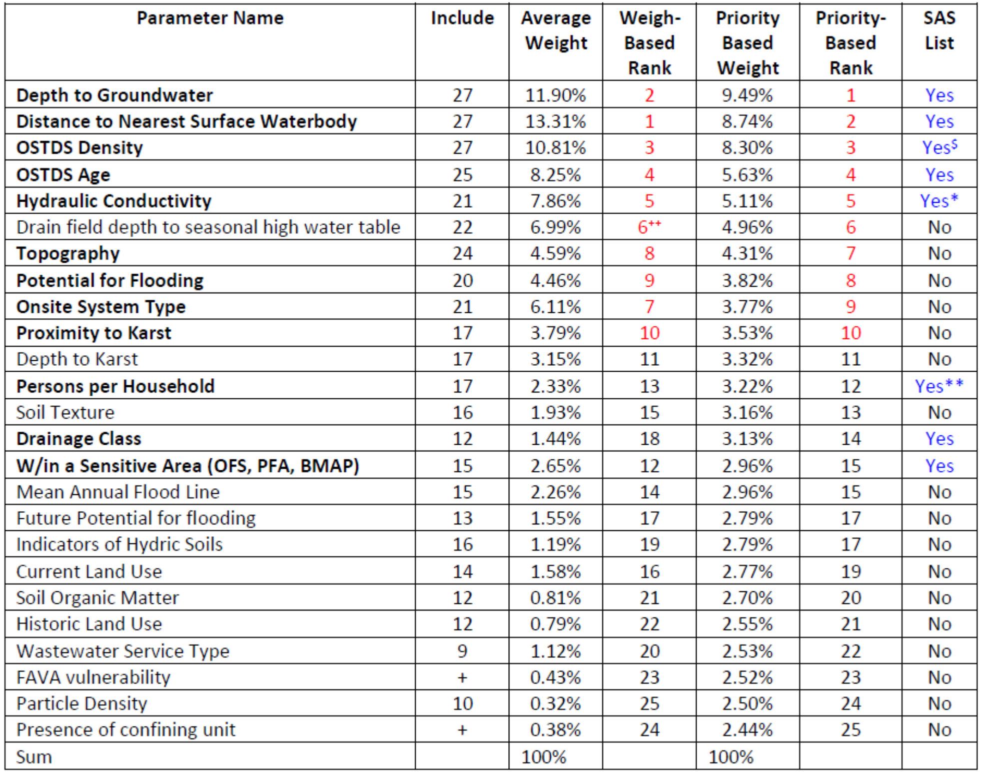
Parameter Identification (CCS –SAS survey results)



Three most important parameters in general

Parameter ranking (CCS-SAS workshop)

Table 4. Summary table of the 23 parameters discussed in the workshop and the average weights and ranks of these parameters derived from the participants' individual work completed at the start of day 2 of the workshop.



Parameter Name	Include	Average Weight	Weigh-Based Rank	Priority Based Weight	Priority-Based Rank	SAS List
Depth to Groundwater	27	11.90%	2	9.49%	1	Yes
Distance to Nearest Surface Waterbody	27	13.31%	1	8.74%	2	Yes
OSTDS Density	27	10.81%	3	8.30%	3	Yes$
OSTDS Age	25	8.25%	4	5.63%	4	Yes
Hydraulic Conductivity	21	7.86%	5	5.11%	5	Yes*
Drain field depth to seasonal high water table	22	6.99%	6++	4.96%	6	No
Topography	24	4.59%	8	4.31%	7	No
Potential for Flooding	20	4.46%	9	3.82%	8	No
Onsite System Type	21	6.11%	7	3.77%	9	No
Proximity to Karst	17	3.79%	10	3.53%	10	No
Depth to Karst	17	3.15%	11	3.32%	11	No
Persons per Household	17	2.33%	13	3.22%	12	Yes**
Soil Texture	16	1.93%	15	3.16%	13	No
Drainage Class	12	1.44%	18	3.13%	14	Yes
W/in a Sensitive Area (OFS, PFA, BMAP)	15	2.65%	12	2.96%	15	Yes
Mean Annual Flood Line	15	2.26%	14	2.96%	15	No
Future Potential for flooding	13	1.55%	17	2.79%	17	No
Indicators of Hydric Soils	16	1.19%	19	2.79%	17	No
Current Land Use	14	1.58%	16	2.77%	19	No
Soil Organic Matter	12	0.81%	21	2.70%	20	No
Historic Land Use	12	0.79%	22	2.55%	21	No
Wastewater Service Type	9	1.12%	20	2.53%	22	No
FAVA vulnerability	+	0.43%	23	2.52%	23	No
Particle Density	10	0.32%	25	2.50%	24	No
Presence of confining unit	+	0.38%	24	2.44%	25	No
Sum		100%		100%		

CCS-SAS final parameters and weights

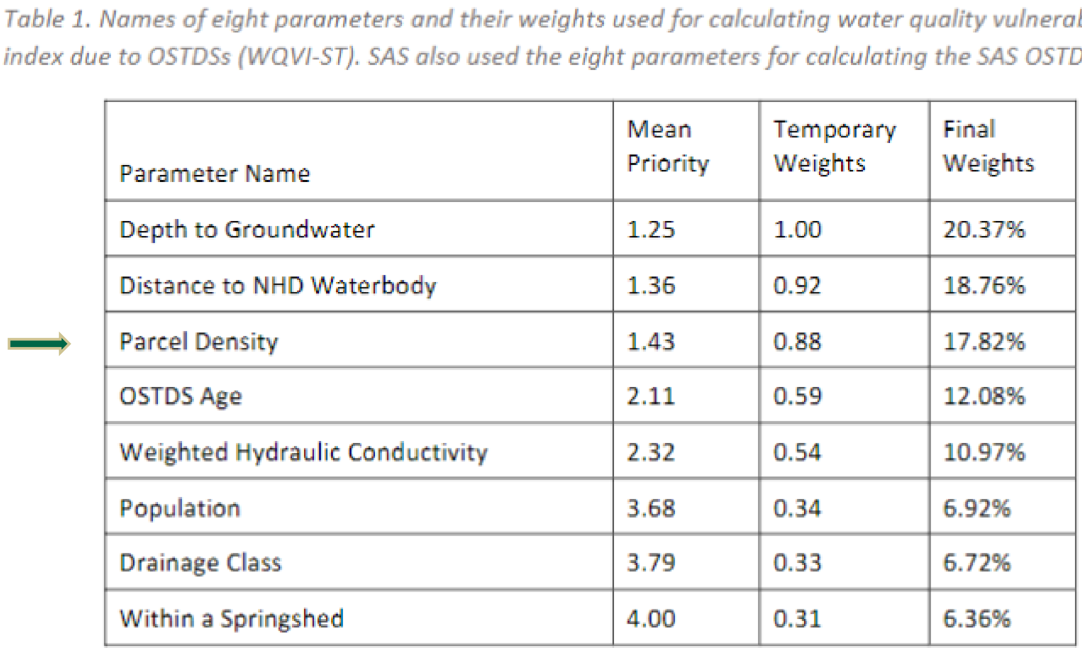


Table 1. Names of eight parameters and their weights used for calculating water quality vulnerability index due to OSTDSs (WQVI-ST). SAS also used the eight parameters for calculating the SAS OSTDS score.

Parameter Name	Mean Priority	Temporary Weights	Final Weights
Depth to Groundwater	1.25	1.00	20.37%
Distance to NHD Waterbody	1.36	0.92	18.76%
Parcel Density	1.43	0.88	17.82%
OSTDS Age	2.11	0.59	12.08%
Weighted Hydraulic Conductivity	2.32	0.54	10.97%
Population	3.68	0.34	6.92%
Drainage Class	3.79	0.33	6.72%
Within a Springshed	4.00	0.31	6.36%

USF Parameter Identification

- Distance to nearest surface waterbody
- Depth to groundwater
- Topography (Slope)
- Potential for flooding (FEMA flood risk)
- Hydraulic Conductivity
- Depth to limestone (previously called depth to karst)

➡ Parcel density

Pairwise comparison table

Pairwise Comparison Exercise

Please remember to:

1. Fill out your name and contact information at the top of the pairwise comparison tables.
2. At the end of all pairwise comparison tables there are 2 questions that need to be answered with yes or no. There is also room for comments.
3. Return your word document to us by the end of the workshop.
4. We will stay online in this meeting to answer questions about the exercise or help with technical problems.

Contact information:

Edgar Guerron Orejuela: edgarguerron@usf.edu

Kai Rains: krains@usf.edu

Appendix 5

Worksheet used to perform pairwise comparison of parameters during workshop held on June 5th, 2023.

Parameters pairwise comparison for St. Lucie Co.

Name of respondent:

Email:

Importance scale

Scale	1	3	5	7	9
Importance	Equal	Moderate	Strong	Very Strong	Extreme

Even numbers are also possible in the scale and express intermediate importance.

Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Distance to waterbody				Depth to Groundwater									
Distance to waterbody				Topography									
Distance to waterbody				Potential for flooding									
Distance to waterbody				Hydraulic Conductivity									
Distance to waterbody				Depth to limestone									

Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Depth to Groundwater				Topography									
Depth to Groundwater				Potential for flooding									
Depth to Groundwater				Hydraulic Conductivity									
Depth to Groundwater				Depth to limestone									

Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Topography				Potential for flooding									
Topography				Hydraulic Conductivity									
Topography				Depth to limestone									

Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Potential for flooding				Hydraulic Conductivity									
Potential for flooding				Depth to limestone									

Which parameter is more important? Or are they equal?					How much more important?								
					1	2	3	4	5	6	7	8	9
Parameter	>	=	<	Parameter									
Hydraulic Conductivity				Depth to limestone									

Would your parameters be different in different regions? Yes or No

Would you rank the parameters different in different regions? Yes or No

Comments:

Appendix 6

List of Comments Entered by Respondents (SMEs).

Participant 1

Would your parameters be different in different regions? No

Would you rank the parameters different in different regions? No

Participant 2

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

Consider proximity to sewer line.

Participant 3

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Participant 4

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

Certain areas could be more sensitive to nutrient loading. Parameters may need to be different in specific areas of critical concern or known environmental impacts.

Participant 5

Participant did not enter responses to the two regionalization questions and had no comments

Participant 6

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

I understand that the point of this study is to assist authorities in making the best decisions possible. I feel that by removing the system density or lot size parameters based on the idea that lot densities etc. can change as lots are subdivided does a disservice to the intent of the information. In my opinion, all these parameters can and do change. While it may not be feasible for you to include cost benefit analysis, I feel that it would be beneficial to the intent of the study to include some sort of lot size or OSTDS density parameter as well as to look at the average system age.

Some discussion was had concerning barrier islands. In response to some of the other participants' comments in that area, I would have to verify with County and City Utility Systems Departments but, to my knowledge, most of both islands are already served by sewer. Only 3 smallish neighborhoods exist where sewer has not been supplied: Ft Pierce Shores, Coral Cove, and Queens Cove.

Admittedly, I am not near the quality of field technical expert some of your other panelists were, but to what others stated during the discussion, I think it would be beneficial to elaborate more on the specifics of each parameter and how they would be measured. They are currently too vague to ascertain potent information from field technical experts. In that respect, I completed the pairwise comparison as a "generally I think" which of each is more important.

I understand how this study will be beneficial to the Utility Systems Departments as well as county and local governments, but I think that it could be important and valuable to include some cost benefit analysis into the parameters (ie, distance to existing sewer). That said, I think your study without CBA could be more beneficial when viewed from the other side of the aisle. Where is it more important that when sewer is not a feasible option, some sort of nitrogen reducing or performance-based system be installed?

Participant 7

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

Since there is little topography in St. Lucie County and the subsurface strata are not as karstified as other parts of the state I would rank some parameters differently. Some of the inland counties in Florida are not vulnerable to flooding or rising sea levels so that parameter would be rated less important in those areas. Topography along some of Florida's geomorphic ridges might be rated as a more influential parameter than in St. Lucie County.

Participant 8

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

I would rate potential for flooding less highly in non-coastal areas. I would rate karst more highly in other areas.

I would rate topography (slope) more important than I did here in areas where slope is more likely to be a strong driving factor in differential movement of water.

In St Lucie, I expect the high water table, the low elevation ground surface (which makes floods far-reaching), the presence of sandy soils, the danger of coastal flooding, and the high connectivity between the fast moving canals and the down gradient waterways to be of prime importance.

Population or parcel density was not considered as a physical factor but I think this was short-sighted. A high population density means waterways are being incrementally impacted by contaminated runoff, high peakflows, low baseflows, and atmospheric deposition. If you add septic to an area already compromised by a high population density, you are at higher risk of that septic being a very impactful final blow.

Participant 9

Would your parameters be different in different regions? No

Would you rank the parameters different in different regions? Yes

Comments:

Springs region will be different.

Participant 10

Would your parameters be different in different regions? Yes (distance to nearest spring might be a concern)

Would you rank the parameters different in different regions? Yes

Comments: Depth to limestone would be more important in areas where I would expect limestone to be more involved in transport (depending on the layer chosen for hyraulic conductivity, it would correlate with that)

Note: Depth to groundwater importance has a step function, beyond a not very large number (eg. About 4 feet), little additional effects is expected. Even for lower numbers, new construction standards can keep effect the same

Participant 11

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

(1) Organic carbon content and pyrophosphate extractable and citrate dithionite extractable iron and aluminum contents can be important parameters influencing the reactive transport of nitrogen and phosphorus in surficial aquifer. These data are readily available in the SSURGO coverage.

(2) Please clarify exactly what GIS data layers will be used to specify the distance to waterbody. Some of the waterbody types, such as wetland and agricultural ditches, are not covered by any state water quality criteria. Existence of these waterbodies between the septic systems and the receiving waterbodies to be protected (those that are covered by state water quality criteria) may help reduce the nutrient load from onsite systems to the receiving water to be protected through uptake by emergent aquatic vegetation, benthic algal and periphyton communities. Wetland may also remove nitrogen through denitrification. If these waterbodies are included in the dataset, it would be hard to define whether being close to these waterbodies makes the subject area more vulnerable or less vulnerable to onsite system nutrient loading.

(3) Since no onsite system data layer will be included in the analyses, how is the distance to the waterbody defined? Is it the distance between the centriole or boundary of certain developed or to-be developed area and the edge of the receiving water or is it the distance between the centriole or boundary of each parcel and the receiving waterbody? Or is it the distance between each grid and the receiving waterbody in a raster file?

Participant 12

Would your parameters be different in different regions? Yes

Would you rank the parameters different in different regions? Yes

Comments:

The distance to waterbody is less important than the vertical depth, because the extent of nitrogen removal due to denitrification depends on the extent of converting ammonium to nitrate over nitrification. The extent of nitrification depends solely on the depth to groundwater. I assigned the value of 3 to the importance scale because denitrification is also important.

The distance to waterbody is probably only slightly more important than topography (slope). The two variables are all important to nitrogen travel time, t = L/v. The distance is L, and the topography (slope) determine v. But velocity also depends on hydraulic conductivity.

The distance to waterbody should be moderately more important than the potential for flooding, while depth to groundwater should be small in areas with high potential for flooding. But I have not studied these two variables together.

The distance to waterbody should be equally important with hydraulic conductivity, because they are all related to travel velocity.

The distance to waterbody should be substantially more important than depth to limestone, because the depth of limestone does not appear an important factor to groundwater flow and solute transport in surficial aquifers.

The depth to groundwater should be the most important variable to nitrogen reduction, because it controls the extent of nitrification. The depth to groundwater should be moderately more important than topography, because topography may not vary much at the site. The depth may be only slightly more important to the potential for flooding, because the two variables should be strongly related, given than depth to groundwater is small in areas with high potential for flooding. The depth to groundwater should be moderately more important than hydraulic conductivity, because the nitrification process related to depth to groundwater should be more important than hydraulic conductivity with respect to nitrogen removal.

Topography should be less important than potential for flooding, because the latter is related to the depth to groundwater, which is the most important variable.Topography (slope) should be equally as important as hydraulic conductivity, because they play the same role mathematically to determine Darcy velocity. Topography should be more important than the depth to limestone, which is probably the least important variable here.

Potential for flooding should be slightly less important than hydraulic conductivity, because hydraulic conductivity is important everywhere but potential for flooding may be only important in certain areas. Potential for flooding should be more important than depth to limestone.

Hydraulic conductivity should be strongly more important than depth to limestone.

Appendix 7

Respondents (SMEs) pairwise comparison matrices.

Participant 1

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	1	2	1	1/3	2
Depth to Groundwater		1	**1**	3	1	1	2
Topography		1/2	1/3	**1**	1/3	1/3	1/2
Potential for Flooding		1	1	3	**1**	1/2	2
Hydraulic Conductivity		3	1	3	2	**1**	2
Depth to Limestone		1/2	1/2	2	1/2	1/2	**1**
	Total	7.00	4.83	14.00	5.83	3.67	9.50

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.14	0.21	0.14	0.17	0.09	0.21
Depth to Groundwater		0.14	0.21	0.21	0.17	0.27	0.21
Topography		0.07	0.07	0.07	0.06	0.09	0.05
Potential for Flooding		0.14	0.21	0.21	0.17	0.14	0.21
Hydraulic Conductivity		0.43	0.21	0.21	0.34	0.27	0.21
Depth to Limestone		0.07	0.10	0.14	0.09	0.14	0.11
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.161	16.09
0.203	20.31
0.069	6.88
0.180	18.04
0.279	27.93
0.108	10.75
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.168450319	0.03	1.24

CR=CI/RI
0.027169406

Pairwise comparisons

Participant 2

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	1/2	7	4	5	3
Depth to Groundwater		2	**1**	7	2	3	1
Topography		1/7	1/7	**1**	1/6	1	3
Potential for Flooding		1/4	1/2	6	**1**	2	1
Hydraulic Conductivity		1/5	1/3	1	1/2	**1**	4
Depth to Limestone		1/3	1	1/3	1	1/4	**1**
	Total	3.93	3.48	22.33	8.67	12.25	13.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.25	0.14	0.31	0.46	0.41	0.23
Depth to Groundwater		0.51	0.29	0.31	0.23	0.24	0.08
Topography		0.04	0.04	0.04	0.02	0.08	0.23
Potential for Flooding		0.06	0.14	0.27	0.12	0.16	0.08
Hydraulic Conductivity		0.05	0.10	0.04	0.06	0.08	0.31
Depth to Limestone		0.08	0.29	0.01	0.12	0.02	0.08
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.302	30.21
0.277	27.72
0.076	7.56
0.139	13.86
0.106	10.64
0.100	10.00
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	7.644735947	0.33	1.24

CR=CI/RI
0.265279991

Participant 3

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	1	9	9	1	9
Depth to Groundwater		1	**1**	9	9	1	9
Topography		1/9	1/9	**1**	1	1/5	5
Potential for Flooding		1/9	1/9	1	**1**	1/3	3
Hydraulic Conductivity		1	1	5	3	**1**	9
Depth to Limestone		1/9	1/9	1/5	1/3	1/9	**1**
	Total	3.33	3.33	25.20	23.33	3.64	36.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.30	0.30	0.36	0.39	0.27	0.25
Depth to Groundwater		0.30	0.30	0.36	0.39	0.27	0.25
Topography		0.03	0.03	0.04	0.04	0.05	0.14
Potential for Flooding		0.03	0.03	0.04	0.04	0.09	0.08
Hydraulic Conductivity		0.30	0.30	0.20	0.13	0.27	0.25
Depth to Limestone		0.03	0.03	0.01	0.01	0.03	0.03
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.311	31.12
0.311	31.12
0.057	5.72
0.054	5.40
0.242	24.19
0.025	2.45
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.539721541	0.11	1.24

CR=CI/RI
0.087051861

Participant 4

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	1	2	2	1	1/5
Depth to Groundwater		1	**1**	2	2	1	1
Topography		1/2	1/2	**1**	1	1	1
Potential for Flooding		1/2	1/2	1	**1**	1/5	1/5
Hydraulic Conductivity		1	1	1	5	**1**	1
Depth to Limestone		5	1	1	5	1	**1**
	Total	9.00	5.00	8.00	16.00	5.20	4.40

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.11	0.20	0.25	0.13	0.19	0.05
Depth to Groundwater		0.11	0.20	0.25	0.13	0.19	0.23
Topography		0.06	0.10	0.13	0.06	0.19	0.23
Potential for Flooding		0.06	0.10	0.13	0.06	0.04	0.05
Hydraulic Conductivity		0.11	0.20	0.13	0.31	0.19	0.23
Depth to Limestone		0.56	0.20	0.13	0.31	0.19	0.23
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.154	15.40
0.184	18.43
0.127	12.71
0.071	7.12
0.195	19.47
0.269	26.88
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.657691013	0.13	1.24

CR=CI/RI

0.106079196

Participant 5

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	2	5	7	5	6
Depth to Groundwater		1/2	**1**	4	7	3	4
Topography		1/5	1/4	**1**	5	1/3	1/4
Potential for Flooding		1/7	1/7	1/5	**1**	1/3	1/4
Hydraulic Conductivity		1/5	1/3	3	3	**1**	3
Depth to Limestone		1/6	1/4	4	4	1/3	**1**
	Total	2.21	3.98	17.20	27.00	10.00	14.50

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.45	0.50	0.29	0.26	0.50	0.41
Depth to Groundwater		0.23	0.25	0.23	0.26	0.30	0.28
Topography		0.09	0.06	0.06	0.19	0.03	0.02
Potential for Flooding		0.06	0.04	0.01	0.04	0.03	0.02
Hydraulic Conductivity		0.09	0.08	0.17	0.11	0.10	0.21
Depth to Limestone		0.08	0.06	0.23	0.15	0.03	0.07
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.403	40.32
0.258	25.76
0.075	7.45
0.033	3.33
0.128	12.78
0.104	10.36
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.876005499	0.18	1.24

CR=CI/RI
0.14129121

Pairwise comparisons

Participant 6

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	2	3	3	3	5
Depth to Groundwater		1/2	**1**	3	3	3	5
Topography		1/3	1/3	**1**	1/3	1/3	5
Potential for Flooding		1/3	1/3	3	**1**	1/3	3
Hydraulic Conductivity		1/3	1/3	3	3	**1**	5
Depth to Limestone		1/5	1/5	1/5	1/3	1/5	**1**
	Total	2.70	4.20	13.20	10.67	7.87	24.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.37	0.48	0.23	0.28	0.38	0.21
Depth to Groundwater		0.19	0.24	0.23	0.28	0.38	0.21
Topography		0.12	0.08	0.08	0.03	0.04	0.21
Potential for Flooding		0.12	0.08	0.23	0.09	0.04	0.13
Hydraulic Conductivity		0.12	0.08	0.23	0.28	0.13	0.21
Depth to Limestone		0.07	0.05	0.02	0.03	0.03	0.04
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.324	32.41
0.254	25.36
0.093	9.34
0.115	11.52
0.174	17.45
0.039	3.92
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.715408742	0.14	1.24

CR=CI/RI
0.115388507

Participant 7

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	1	5	3	1/5	1/5
Depth to Groundwater		1	**1**	3	5	1/3	1
Topography		1/5	1/3	**1**	1/3	1/5	1/3
Potential for Flooding		1/3	1/5	3	**1**	3	3
Hydraulic Conductivity		5	3	5	1/3	**1**	5
Depth to Limestone		5	1	3	1/3	1/5	**1**
	Total	12.53	6.53	20.00	10.00	4.93	10.53

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.08	0.15	0.25	0.30	0.04	0.02
Depth to Groundwater		0.08	0.15	0.15	0.50	0.07	0.09
Topography		0.02	0.05	0.05	0.03	0.04	0.03
Potential for Flooding		0.03	0.03	0.15	0.10	0.61	0.28
Hydraulic Conductivity		0.40	0.46	0.25	0.03	0.20	0.47
Depth to Limestone		0.40	0.15	0.15	0.03	0.04	0.09
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.140	14.04
0.174	17.42
0.037	3.71
0.200	20.00
0.303	30.31
0.145	14.51
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	8.664013568	0.53	1.24

CR=CI/RI
0.429679608

Participant 8

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	6	8	1/2	2	8
Depth to Groundwater		1/6	**1**	4	1/8	1/4	4
Topography		1/8	1/4	**1**	1/9	1/6	2
Potential for Flooding		2	8	9	**1**	4	9
Hydraulic Conductivity		1/2	4	6	1/4	**1**	7
Depth to Limestone		1/8	1/4	1/2	1/9	1/7	**1**
	Total	3.92	19.50	28.50	2.10	7.56	31.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.26	0.31	0.28	0.24	0.26	0.26
Depth to Groundwater		0.04	0.05	0.14	0.06	0.03	0.13
Topography		0.03	0.01	0.04	0.05	0.02	0.06
Potential for Flooding		0.51	0.41	0.32	0.48	0.53	0.29
Hydraulic Conductivity		0.13	0.21	0.21	0.12	0.13	0.23
Depth to Limestone		0.03	0.01	0.02	0.05	0.02	0.03
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.267	26.75
0.076	7.60
0.037	3.66
0.422	42.22
0.170	17.01
0.028	2.77
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.60225077	0.12	1.24

CR=CI/RI
0.097137221

Pairwise comparisons

Participant 9

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	3	1	6	1	6
Depth to Groundwater		1/3	**1**	1/3	3	1/3	3
Topography		1	3	**1**	6	1	6
Potential for Flooding		1/6	1/3	1/6	**1**	1/6	1
Hydraulic Conductivity		1	3	1	6	**1**	6
Depth to Limestone		1/6	1/3	1/6	1	1/6	**1**
	Total	3.67	10.67	3.67	23.00	3.67	23.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.27	0.28	0.27	0.26	0.27	0.26
Depth to Groundwater		0.09	0.09	0.09	0.13	0.09	0.13
Topography		0.27	0.28	0.27	0.26	0.27	0.26
Potential for Flooding		0.05	0.03	0.05	0.04	0.05	0.04
Hydraulic Conductivity		0.27	0.28	0.27	0.26	0.27	0.26
Depth to Limestone		0.05	0.03	0.05	0.04	0.05	0.04
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.270	27.02
0.105	10.46
0.270	27.02
0.042	4.24
0.270	27.02
0.042	4.24
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.039134552	0.01	1.24

CR=CI/RI
0.006312025

Participant 10

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	4	2	8	3	5
Depth to Groundwater		1/4	**1**	1/2	5	1/3	3
Topography		1/2	2	**1**	5	2	5
Potential for Flooding		1/8	1/5	1/5	**1**	1/5	1/3
Hydraulic Conductivity		1/3	3	1/2	5	**1**	4
Depth to Limestone		1/5	1/3	1/5	3	1/4	**1**
	Total	2.41	10.53	4.40	27.00	6.78	18.33

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.42	0.38	0.45	0.30	0.44	0.27
Depth to Groundwater		0.10	0.09	0.11	0.19	0.05	0.16
Topography		0.21	0.19	0.23	0.19	0.29	0.27
Potential for Flooding		0.05	0.02	0.05	0.04	0.03	0.02
Hydraulic Conductivity		0.14	0.28	0.11	0.19	0.15	0.22
Depth to Limestone		0.08	0.03	0.05	0.11	0.04	0.05
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.377	37.68
0.118	11.84
0.230	22.96
0.034	3.35
0.181	18.13
0.060	6.04
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.407151219	0.08	1.24

CR=CI/RI
0.065669551

Participant 11

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	3	4	3	4	6
Depth to Groundwater		1/3	**1**	2	1	2	3
Topography		1/4	1/2	**1**	1/2	1	3
Potential for Flooding		1/3	1	2	**1**	2	3
Hydraulic Conductivity		1/4	1/2	1	1/2	**1**	2
Depth to Limestone		1/6	1/3	1/3	1/3	1/2	**1**
	Total	2.33	6.33	10.33	6.33	10.50	18.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.43	0.47	0.39	0.47	0.38	0.33
Depth to Groundwater		0.14	0.16	0.19	0.16	0.19	0.17
Topography		0.11	0.08	0.10	0.08	0.10	0.17
Potential for Flooding		0.14	0.16	0.19	0.16	0.19	0.17
Hydraulic Conductivity		0.11	0.08	0.10	0.08	0.10	0.11
Depth to Limestone		0.07	0.05	0.03	0.05	0.05	0.06
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.413	41.29
0.168	16.82
0.104	10.40
0.168	16.82
0.095	9.47
0.052	5.20
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.09906094	0.02	1.24

CR=CI/RI
0.01597757

Participant 12

Pairwise comparisons

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		**1**	1/3	2	3	1	6
Depth to Groundwater		3	**1**	3	2	3	7
Topography		1/2	1/3	**1**	1/2	1	4
Potential for Flooding		1/3	1/2	2	**1**	1/3	5
Hydraulic Conductivity		1	1/3	1	3	**1**	5
Depth to Limestone		1/6	1/7	1/4	1/5	1/5	**1**
	Total	6.00	2.64	9.25	9.70	6.53	28.00

Standardized Matrix

Parameters		Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone
Distance to Waterbody		0.17	0.13	0.22	0.31	0.15	0.21
Depth to Groundwater		0.50	0.38	0.32	0.21	0.46	0.25
Topography		0.08	0.13	0.11	0.05	0.15	0.14
Potential for Flooding		0.06	0.19	0.22	0.10	0.05	0.18
Hydraulic Conductivity		0.17	0.13	0.11	0.31	0.15	0.18
Depth to Limestone		0.03	0.05	0.03	0.02	0.03	0.04
	Total	1.00	1.00	1.00	1.00	1.00	1.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Eigenvector	Eigenvector %
0.198	19.76
0.353	35.30
0.111	11.08
0.132	13.23
0.174	17.36
0.033	3.26
1.000	100.00

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.475082241	0.10	1.24

CR=CI/RI

0.076626168

Geometric Mean

Parameters	**Distance to Waterbody**	**Depth to Groundwater**	**Topography**	**Potential for Flooding**	**Hydraulic Conductivity**	**Depth to Limestone**
Distance to Waterbody	1	1.513085749	3.403867512	3.15689812	1.490270497	3.013057334
Depth to Groundwater	0.660901076	1	2.48115859	2.217993431	1.034366083	2.837278876
Topography	0.293783467	0.403037518	1	0.737093891	0.530230348	1.902604603
Potential for Flooding	0.316766637	0.450857963	1.356679267	1	0.595163442	1.491814039
Hydraulic Conductivity	0.671019122	0.966775706	1.885972774	1.680210727	1	3.800218666
Depth to Limestone	0.331888806	0.352450374	0.52559528	0.670324835	0.263142753	1
Total	3.274359107	4.69	10.65	9.46	4.91	14.04

Standardized Matrix

Parameters	Distance to Waterbody	Depth to Groundwater	Topography	Potential for Flooding	Hydraulic Conductivity	Depth to Limestone	Eigenvector	Eigenvector %
Distance to Waterbody	0.31	0.32	0.32	0.33	0.30	0.21	0.300	30.0
Depth to Groundwater	0.20	0.21	0.23	0.23	0.21	0.20	0.216	21.6
Topography	0.09	0.09	0.09	0.08	0.11	0.14	0.098	9.8
Potential for Flooding	0.10	0.10	0.13	0.11	0.12	0.11	0.109	10.9
Hydraulic Conductivity	0.20	0.21	0.18	0.18	0.20	0.27	0.207	20.7
Depth to Limestone	0.10	0.08	0.05	0.07	0.05	0.07	0.070	7.0
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.000	100.00

n =	6
n-1 =	5
Random Consistency Index for n = 6 (table value) =	1.24

Principal Eigen Value		Consistency index (CI)	RI for n=6
lamda(max)	6.074910627	0.01	1.24

CR=CI/RI
0.012082359

Appendix 8

Summary of weights assigned to individual parameters as calculated from the pairwise comparisons provided by respondents (SMEs).

Table showing the participant number and the individual weights calculated based on each participant’s pairwise comparisons. The CR values represents the consistency ratio calculated for each participant’s pairwise comparisons.

Participant number	Priority 1	Priority 1 value	Priority 2	Priority 2 value	Priority 3	Priority 3 value	Priority 4	Priority 4 value	Priority 5	Priority 5 value	Priority 6	Priority 6 value	CR
1	Hydraulic conductivity	27.93	Depth to groundwater	20.31	Potential for flooding	18.04	Distance to water body	16.09	Depth to limestone	10.75	Topography	6.88	0.027
2	Distance to water body	30.21	Depth to groundwater	27.72	Potential for flooding	13.86	Hydraulic conductivity	10.64	Depth to limestone	10	Topography	7.56	0.265
3	Distance to water body	31.12	Depth to groundwater	31.12	Hydraulic conductivity	24.19	Topography	5.72	Potential for flooding	5.4	Depth to limestone	2.45	0.087
4	Depth to limestone	26.88	Hydraulic conductivity	19.47	Depth to groundwater	18.43	Distance to water body	15.4	Topography	12.71	Potential for flooding	7.12	0.106
5	Distance to water body	40.32	Depth to groundwater	25.76	Hydraulic conductivity	12.78	Depth to limestone	10.36	Topography	7.45	Potential for flooding	3.33	0.141
6	Distance to water body	32.41	Depth to groundwater	25.36	Hydraulic conductivity	17.45	Potential for flooding	11.52	Topography	9.34	Depth to limestone	3.92	0.115
7	Hydraulic conductivity	30.31	Potential for flooding	20	Depth to groundwater	17.42	Depth to limestone	14.51	Distance to waterbody	14.04	Topography	3.71	0.429
8	Potential for flooding	42.22	Distance to water body	26.75	Hydraulic conductivity	17.01	Depth to groundwater	7.6	Topography	3.66	Depth to limestone	2.77	0.097
9	Distance to water body	27.02	Topography	27.02	Hydraulic conductivity	27.02	Depth to groundwater	10.46	Potential for flooding	4.24	Depth to limestone	4.24	0.00631
10	Distance to water body	37.68	Topography	22.96	Hydraulic conductivity	18.13	Depth to groundwater	11.84	Depth to limestone	6.04	Potential for flooding	3.35	0.0656
11	Distance to water body	41.29	Depth to groundwater	16.82	Potential for flooding	16.82	Topography	10.4	Hydraulic conductivity	9.47	Depth to limestone	5.2	0.0159
12	Depth to groundwater	35.3	Distance to water body	19.76	Hydraulic conductivity	17.36	Potential for flooding	13.23	Topography	11.08	Depth to limestone	3.26	0.0766

Appendix 9

Priority Geospatial Datasets.

Parameter	Dataset	Owner	Source location	AOI coverage Description	Comments
Depth to groundwater	Water table depth - Annual minimum	USDA NRCS	https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx	100%	Depth to water table is estimated down to 80 inches, dataset is available statewide. It is produced by USDA NRCS but can be downloaded directly from NRCS or through ESRI : https://www.arcgis.com/home/item.html?id=cdc49bd63ea54dd2977f3f2853e07fff
Distance to waterbody	Florida NHD Flowlines (24k), Large Scale, Florida NHD Waterbodies (24k), Large Scale	USGS,FDEP	https://geodata.dep.state.fl.us/explore?groupIds=0bdf5110a2d7476b931b18b2f58686d5&layout=list&query=nhd	100%	Distance to waterbody or nearest flowline can be derived from this resource once the origin point has been defined. See report text and figures for more information.
Topography (Slope)	LiDAR derived DEM	FDEP	https://www.floridagio.gov/pages/lidar-resources	100%	DEMs, slope and aspect can be generated from this dataset. If a tile mosaic is desired, contact Kim Jackson (GIO) for regional contacts
Potential for flooding	Flood Hazard Boundaries	FEMA, ESRI	https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd	100%	This dataset includes an assessment of flood risk
Hydraulic conductivity	Saturated Hydraulic Conductivity	USDA NRCS	https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx	100% for vertical flow 0% for lateral flow	Saturated hydraulic conductivity ratings for vertical flow are included in the soil survey data. See report text for additional considerations particulalry concerning horizontal or lateral flow. The dataset is produced by USDA NRCS but can be downloaded directly from NRCS or through ESRI : https://www.arcgis.com/home/item.html?id=cdc49bd63ea54dd2977f3f2853e07fff
Depth to limestone	See comment	FGS	https://geodata.dep.state.fl.us/datasets/80f5b31c966d4b0aaf57b06f2503e2f2_6/explore	0%	There is no existing layer or dataset that properly documents depth to limestone. See report text for additional discussion.

Appendix 10

List of instructional meetings.

Task 3 List of Instructional, Capacity Building, and Hand-off Meetings:

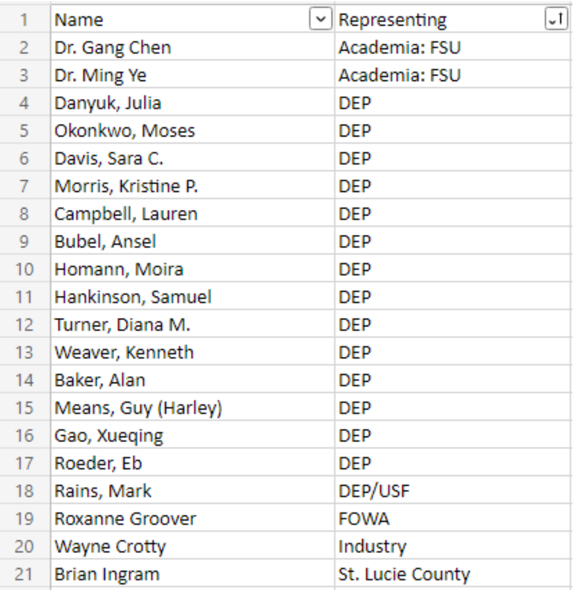
June 28, 2023: Representatives from the USF Ecohydrology Research Group (Edgar Guerron-Orejuela, Kai Rains) met virtually with FDEP to officially handoff the project and finalize the “capacity building” component of this effort. In attendance from FDEP were Julia Danyuk and Moses Okonkwo.

June 23, 2023: Representatives from the USF Ecohydrology Research Group (Edgar Guerron-Orejuela, Kai Rains) met virtually with FDEP to discuss geospatial dataset limitations and the dataset transformations that will be required before the final map can be constructed. In attendance from FDEP were Sara Davis, Julia Danyuk, and Moses Okonkwo.

June 20, 2023: Representatives from the USF Ecohydrology Research Group (Edgar Guerron-Orejuela, Kai Rains) met virtually with FDEP to explain standard processes for ranking attributes within geospatial datasets in preparation for construction of the final map. Also discussed: geospatial dataset limitations and the dataset transformations that will be required before the final map can be constructed. In attendance from FDEP were Julia Danyuk, and Moses Okonkwo.

June 16, 2023: Representatives from the USF Ecohydrology Research Group (Edgar Guerron-Orejuela, Kai Rains, Hayley Sawh Ramdeh) met virtually with FDEP to explain the mechanics and calculation behind the AHP process. In attendance from FDEP were Julia Danyuk and Moses Okonkwo.

June 5, 2023: Representatives from the USF ERG and the USF Water Institute (Edgar Guerron-Orejuela, Kai Rains, Shawn Landry) a virtual presentation explaining the Analytical Hierarchy Process method and showcasing how it will be applied to the contracted project. A general discussion followed. The meeting was recorded by FDEP. The agenda and list of attendees are below:



1	Name	Representing
2	Dr. Gang Chen	Academia: FSU
3	Dr. Ming Ye	Academia: FSU
4	Danyuk, Julia	DEP
5	Okonkwo, Moses	DEP
6	Davis, Sara C.	DEP
7	Morris, Kristine P.	DEP
8	Campbell, Lauren	DEP
9	Bubel, Ansel	DEP
10	Homann, Moira	DEP
11	Hankinson, Samuel	DEP
12	Turner, Diana M.	DEP
13	Weaver, Kenneth	DEP
14	Baker, Alan	DEP
15	Means, Guy (Harley)	DEP
16	Gao, Xueqing	DEP
17	Roeder, Eb	DEP
18	Rains, Mark	DEP/USF
19	Roxanne Groover	FOWA
20	Wayne Crotty	Industry
21	Brian Ingram	St. Lucie County

AT015 OSTDS SME Workshop Agenda

- Introduction to Analytic Hierarchy Process (AHP) (1 hr)
  - General overview
  - AHP in practice: development of a geospatial tool using AHP and related confidence metrics to support groundwater resource management
  - Q&A
- Break (15 min)
- AHP activity overview and directions (30 min)
  - Introduction and demonstration of pairwise comparison exercise
  - Process re-cap and future steps
  - Open discussion and Q&A
- SME AHP activity (1 hr)
  - Independent pairwise comparison of parameters by SMEs with live support by USF
  - Submission of AHP activity by workshop participants