Pilot Scale Development of a Septic-to-Sewer Conversion Prioritization Tool Using Analytical Hierarchy Process, Phase II: Landscape Vulnerability

Task 4: Final Report

DEP Agreement # AT020

Prepared for the Office of Environmental Accountability and Transparency

Florida Department of Environmental Protection

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List of Abbreviations

Abbreviations	Definitions
AHP	Analytic Hierarchy Process
ArcNLET	ArcGIS-Based Nitrate Load Estimation Toolkit
BLM	Bureau of Land Management
DEM	Digital Elevation Model
ERG	Ecohydrology Research Group
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
FGS	Florida Geological Survey
FIRM	Flood Insurance Rate Map
LARNLoad	Landscape Assessment of Risk to Nutrient Loading to Waterbodies
NFHL	National Flood Hazard Layer
NHDPlus HR	National Hydrography Dataset Plus High Resolution
NRCS	Natural Resources Conservation Service
OEAT	Office of Environmental Accountability and Transparency
OSTDS	Onsite Sewage Treatment and Disposal System
PLSS	Public Land Survey System
SFWMD	South Florida Water Management District
SMEs	Subject Matter Experts
SSURGO	Soil Survey Geographic Database
USDA	United States Department of Agriculture
USF	University of South Florida
USGS	United States Geological Survey

Executive Summary

Onsite sewage treatment disposal systems (OSTDS) in Florida number approximately 2.6 million and serve roughly one-third of the population. Nutrient transport from these systems can lead to water quality degradation through excess nutrient loading to nearby waterbodies. The Florida Department of Environmental Protection (FDEP, Department) has identified several factors influencing the impact of OSTDS drain fields on waterbodies, such as distance to waterbody, depth the groundwater, hydraulic conductivity, topography, and the density and age of OSTDS (DEP Agreement No. AT006). While a step in the correct direction, prioritizing these factors is essential for assessing the vulnerability of waterbodies to OSTDS and guiding initiatives like septic-to-sewer conversions and remediation plans.

In Phase I of this project (DEP Agreement No. AT015), the Department partnered with the University of South Florida Ecohydrology Research Group (USF-ERG) to develop an approach to map the landscape-scale risk of nutrient loading to waterbodies from OSTDS, piloting the approach in St. Lucie County, FL. USF-ERG started with the top six physical landscape parameters identified in a previous workshop: distance to waterbody, depth to groundwater, hydraulic conductivity, potential for flooding, topography (slope), and depth to karst (DEP Agreement No. AT006). The Department and the USF-ERG then convened a subject-matter-expert (SME) workshop, with the following objectives (Phase 1, DEP Agreement No. AT015).

- Ensure that the physical landscape parameters were correctly selected, and that sufficient geospatial datasets were readily available.
- Conduct Analytic Hierarchy Process (AHP) analyses to calculate the weights each one of these physical landscape parameters will have within the model.

The results of these analyses were shared with the Department and converted into a geospatial product by the Department of Environmental Protection Office of Environmental Accountability and Transparency (FDEP-OEAT) staff, resulting in a preliminary vulnerability map referred to as the “2023 Draft Map”. During development of the 2023 Draft Map, FDEP-OEAT staff determined some of the datasets contained omissions and/or anomalies that compromised the integrity of the 2023 Draft Map, and that many questions remained regarding the classification of raw values within each parameter into ranks.

This led to Phase II of this project, which is the subject of this report, in which the Department and USF-ERG continued their collaboration with the following tasks (Phase II, DEP Agreement No. AT020).

- Task 1: Review the 2023 Draft Map geodatabase and documentation and provide recommendations regarding parameters and ranking methods.
- Task 2: Investigate model response to changes in a) parameter weights, and b) classification methods for ranking.
- Task 3: Evaluate "validate" the model.

The USF-ERG completed these tasks, which resulted in a revised OSTDS vulnerability model and pilot-scale map. The name of the model has been updated to "Landscape Assessment of Risk to Nutrient Loading to Waterbodies (LARNLoad)", and the pilot-scale map is presented below (Figure 1).

This model and pilot-scale map were evaluated "validated" (Task 3) by two independent assessment methods. Both were conducted on study area locations chosen through a random stratified sampling design and both were conducted blind, i.e., participants were not informed of the risk categories assigned to these locations by LARNLoad. In the first approach, subcontractors directed by Dr. Ming Ye (Florida State University) modeled groundwater nutrient loading using ArcNLET, a numerical model used to estimate nitrate loads to surface waterbodies from OSTDSs, and categorized locations by relative risk based on ArcNLET results. In the second approach, Subject Matter Experts (SMEs) categorized locations by relative risk based on best professional judgement. The risk categories assigned through these independent methods were both in 80% agreement with those assigned by LARNLoad. This high degree of concurrence indicates that LARNLoad can be used independently to assess risk or in concert with other methods with a high degree of confidence.

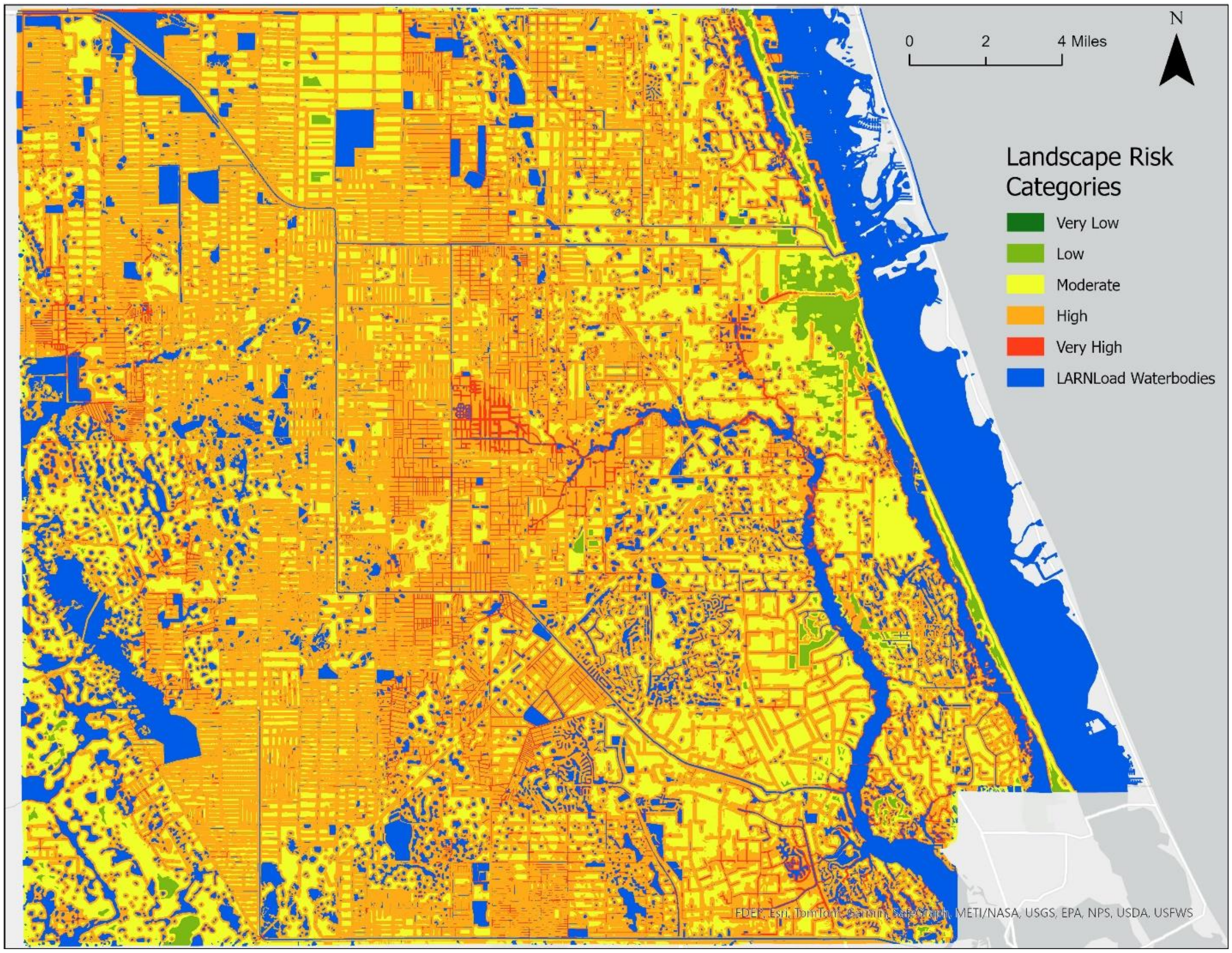

Figure 1. Landscape Assessment of Risk to Nutrient Loading to Waterbodies (LARNLoad) model developed in St. Lucie County.

Summary by Task

Task 1

In Fall 2023, FDEP-OEAT staff applied the model developed as part of DEP Agreement No. AT015 to a set of geospatial datasets and determined the datasets contained omissions and anomalies that compromised the integrity of the end product "2023 Draft Map" and that many questions remained regarding the ranking of the data within each parameter. The model requires accurate and widely available input data. If data for any parameter in any location are inaccurate, the model will return a misleading value for that location. If data for any parameter in any location are missing, the model will return a null value for that location. The USF-ERG was awarded a grant to investigate these issues and either suggest an alternative parameter dataset or propose a strategy for "cleansing" the previously selected datasets to remove nulls and anomalies and to review the methods used to classify raw data into ranks.

Of particular concern to the FDEP-OEAT were the geospatial datasets: *Distance to Waterbody, Hydraulic Conductivity*, and *Depth to Karst*. *Distance to Waterbody* requires a definition of waterbody, including canals, which range from small and shallow (e.g., crop drainage and/or irrigation ditches) to large and deep (e.g., regional conveyance canals). *Hydraulic conductivity* data are acquired from Natural Resources Conservation Service Soil Survey Geographic Database (SSURGO) and should be both accurate and widely available, but there are conditions under which they could be acquired and/or applied incorrectly (e.g., null values under waterbodies). At the recommendation of the Florida Geological Survey (FGS), *Depth to Limestone* was substituted by the FDEP-OEAT for *Depth to Karst*—the dataset originally used in the AHP—due to the lack of availability of depth to karst data.

The USF-ERG conducted a review of these and related concerns and additionally developed recommendations for classifying raw data into ranks.

Primary issues of concern addressed during Phase 2, Task 1 are listed below. The final recommendations and rationale are provided in Appendix A.

1) *What guidelines should govern selection of parameter datasets?*

2) *Which features should be included as "Waterbodies"? Does the mapping provided in the NHDPlus datasets adequately reflect "waterbodies" in the study area?*

3) *The source data for two parameters, Depth to Groundwater and Hydraulic Conductivity, contains nulls. What characterizes the nulls? Should an alternate source dataset be adopted? Or can null values be populated with appropriate values?*

4) *Two parameters, Distance to Waterbody and Slope, require a point of origin. Should the point of origin be the center point of all DEM raster grid cells (2.5 ft resolution)?*

5) *What should be measured for the parameter "Slope"? Should it be the slope between any point in the study area and a waterbody? If so, will anomalies evident in the DEM (e.g.,*

aquatic vegetation and occasional unusually high-water elevations in managed canals) be problematic?

6) *Is the Surficial Geology dataset the most appropriate dataset for "Depth to Karst" aka "Depth to Limestone"? Is this parameter named appropriately?*

7) *How should the parameter raw data be organized into the nine (or fewer) ranks required by the model?*

The USF-ERG presented recommendations for each of these questions to FDEP-OEAT (Appendix A) and worked collaboratively to implement the recommendations and develop the final product, LARNLoad (Figure 1).

Task 2

The USF-ERG conducted a series of sensitivity analyses to assess model responsiveness to changes in model settings. The model was developed to assess landscape vulnerability to OSTDS in the pilot study area, St. Lucie County, FL. Details on the sensitivity analyses are provided in Appendix B.

Sensitivity analyses provide insight into the interactions between model inputs and outputs. The user institutes systematic changes while monitoring output response, revealing the relative importance of individual model inputs or model settings. LARNLoad inputs and settings include six physical landscape parameters, the relative weights assigned to those parameters, the raw data values, the method (e.g., equal intervals, natural breaks, manual intervals) used to classify the raw values within each of the six parameters into nine ranks (Table B1), the ranking hierarchy (e.g., low to high, high to low), and the method by which the nine ranks were consolidated into five final Landscape Risk categories, i.e., Very High, High, Moderate, Low, Very Low (Table B2).

The model reacted predictably to alterations in input settings. These results highlighted the interconnectedness of parameter weights and raw value rankings, demonstrating that modifications to either one impact the distribution of the study area across different risk categories. The central results is that both the parameter weights and the methods for classifying raw values into ranks affect LARNLoad output. Thus, it is important to select these procedures carefully.

Task 3

The USF-ERG assessed the performance of, i.e., “validated”, the Landscape Assessment of Risk to Nutrient Loading to Waterbodies (i.e., LARNLoad) by comparing the risk categories assigned by LARNLoad at locations within the study area to those predicted by two independent methods, subcontractor assessment based on modeled groundwater nutrient loading (ArcNLET) and subject matter expert (SME) assessment based on best professional judgement. In this context, “risk” refers to the risk of nutrient loading to waterbodies if OSTDS effluent was released at these locations. For both methods, the USF-ERG pre-selected polygons for evaluation from the LARNLoad map using a stratified random sampling design. Both the subcontractors and SMEs assigned relative risk categories (higher vs lower) to evaluation polygons blindly, i.e., without knowledge of the risk category assigned by LARNLoad.

In the first approach, “ArcNLET Comparison”, Dr. Ming Ye and Dr. Wei Mao (Florida State University, sub-contractor) modeled groundwater nutrient loading using ArcNLET from 120 point locations designated as OSTDS effluent sources (12 locations within each of 10 evaluation polygons). ArcNLET was developed previously by Dr Ming Ye and collaborators specifically to estimate nitrate loads to surface waterbodies from OSTDSs (Rios et al., 2013, Mao et al. 2024). In this exercise, his team aggregated ArcNLET results by polygon to assign a relative risk category (Higher vs. Lower) to each polygon. The risk categories assigned through these independent methods were in 80% agreement with those assigned by LARNLoad..

In the second approach, “Subject Matter Expert Comparison”, USF-ERG compared the relative risk categories predicted by LARNLoad to those predicted by project subject matter experts (SMEs). Project SMEs are professionals from private, government, and academic sectors who were chosen previously to participate in the Analytical Hierarchy Process workshop (DEP Agreement AT015) to select and rank the LARNLoad parameters. The risk categories assigned by these independent methods also were in 80% agreement with those assigned by LARNLoad.

Although the LARNLoad consistency rating (80%) was identical for the ArcNLET comparison and the SME comparison, the identity of the remaining 20% of evaluation polygons differed across these comparisons. Furthermore, the relative risk categories assigned by SMEs differed across SMEs. The risk categories assigned by four of the seven SMEs were consistent with the risk categories assigned by LARNLoad for over 90% of the evaluation polygons, but for the remaining three SMEs, their risk categorizations were 33% - 87% consistent with those of LARNLoad. Neither LARNLoad nor the relative risk categories based on ArcNLET results or SME best professional judgment were grounded in field data collection. Thus this "validation" is best viewed as an evaluation of the consistency among these methods rather than as a validation. The high consistency rating between LARNLoad and both independent methods indicates LARNLoad can be used independently or in concert with these methods. Additional details are provided in Appendix C.

Limitations and Considerations

LARNLoad was developed and tested in mainland St. Lucie County, FL, where it demonstrated robust and strong performance. However, caution should be exercised when expanding the model to other regions. While effective within the pilot study area, the weights assigned to parameters and the classification methods used to establish ranks may require adaptation to maintain performance and reliability in new project areas. However, if weights or classification methods change regionally, then the risk categories in this study (see Figure 1) should be considered as relative rather than as absolute.

If LARNLoad is expanded beyond this pilot study, the name of the parameter "Depth to Limestone" should be changed to "Surficial Karstic Deposit". "Surficial Karstic Deposit" more accurately characterizes the underlying dataset, which is categorical rather than continuous. Furthermore, although only one type of karstic deposit is present in St. Lucie County, other types (e.g., dolostone) are present in Florida and a more inclusive name for this parameter is recommended.

It is important to note that LARNLoad was not validated by empirical field measurements, thus this is not a validation but rather an evaluation of the consistency of results obtained by the model to those that would be obtained through an independent model (i.e. ArcNLET) or through best professional judgment of experts.

Detailed Description of Geospatial Components of LARNLoad

Nine primary geospatial datasets were developed during this project: LARNLoad, the six geospatial datasets representing LARNLoad parameters, and the validation polygon dataset. A brief technical description of each of these datasets is provided below. All were developed using ESRI ArcGIS Pro 3.1.0. A detailed description of the rationale behind critical procedural steps is provided in Appendix A, and the metadata for these geospatial layers is provided in Appendix F.

1. *LARNLoad map*

   LARNLoad was developed in ArcGIS Pro 3.1.0 by performing a weighted overlay analysis of six physical landscape parameters selected and ranked by importance by subject matter experts (SMEs) using Analytical Hierarchy Process (AHP) (FDEP Agreement AT015) (See Figure 1). USF-ERG synthesized AHP data into a model to generate the LARNLoad parameter weights (Table 1).

   Table 1. Parameters and weights used in LARNLoad.

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 Limestone	7.0

   In LARNLoad, landscape positions are classified according to the potential risk of nutrient loading to waterbodies. The LARNLoad risk ratings reflect the relative risk posed by the physical properties inherent to the landscape. The risk ratings do not reflect related factors that would require more frequent updating such as land use or the current presence/absence of nutrient loading factors. LARNLoad is designed to be used alone or in concert with other project specific information to facilitate decision-making. LARNLoad was evaluated by two independent assessment methods. A comparison between the risk ratings assigned by LARNLoad and those assigned in a blind study by subject matter experts returned a consistency rating of 80%. A comparison between risk ratings assigned by LARNLoad and nutrient loading model (ArcNLET) also returned a consistency rating of 80%.

2. *LARNLoad Waterbodies*

The geospatial dataset *LARNLoad Waterbodies* contains features from NHDPlus HR (waterbody polygons, flowlines polylines (buffered by 2.5 ft), and area polygons) and the Soil Survey Geographic Database (SSURGO) ("water" and "ocean" polygons). These features were merged into a single comprehensive dataset *LARNLoad waterbodies* (Figure 2).

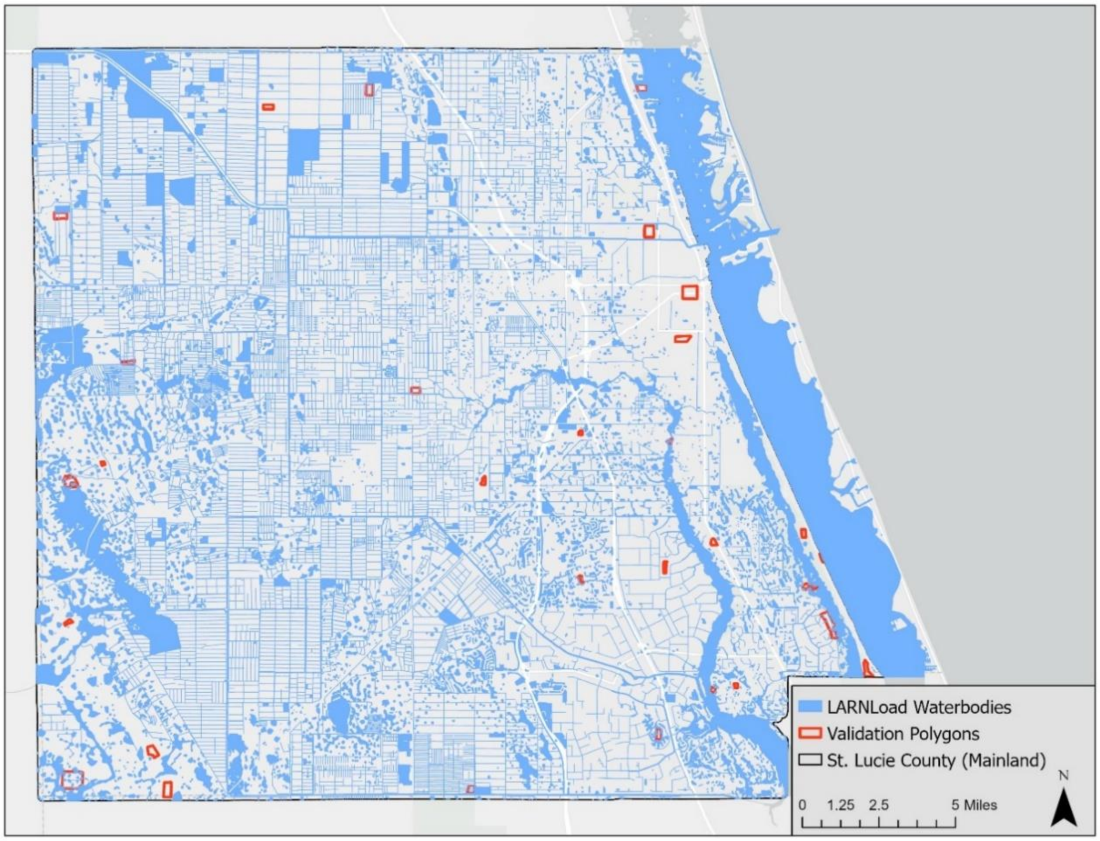

Figure 2. The distribution of waterbodies and of the polygons used to evaluate LARNLoad

3. *Distance to Waterbody*

The geospatial dataset *Distance to Waterbody* depicts the distance from any point (2.5 ft x 2.5ft) in the study area to features contained in the *LARNLoad Waterbodies*. Distance values were calculated using the nearest accumulated distance (Euclidean distance tool, ArcPro) to a LARNLoad waterbody. The range of raw values was 2.5ft – 3197.5ft (Figure 3). The raw values were classified into nine ranks (Table 2. & Figure 9a) to better reflect the fact that although much of the inorganic nitrogen originating from a point source in St.

Lucie County sands is attenuated within the first 100 m, elevated concentrations will be present up to 200 m and, depending on soil type, beyond 200 m (Ye et al. 2023).

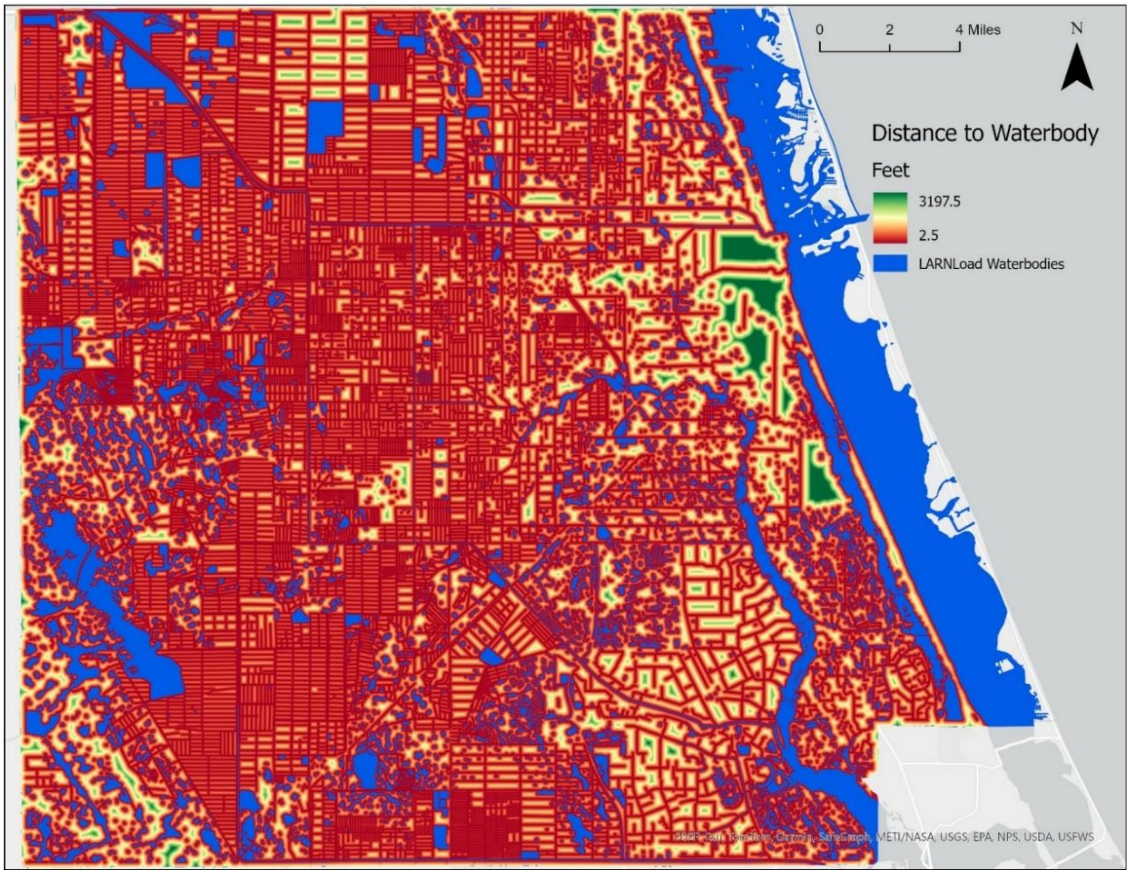

Figure 3. Distance to Waterbody in the study area

Table 2. Classification and ranks for Distance to Waterbody raw values

Classification	Range (m)	Rank
One interval	199.95+	1
One interval	99.97 – 199.95	2
Equal intervals	85.59 – 99.97	3
	71.32 – 85.59	4
	57.06 – 71.32	5
	42.80 – 57.06	6
	28.53 – 42.80	7
	14.02 – 28.53	8
	0.76 – 14.02	9

4. *Depth to Groundwater*

The *Depth to Groundwater* geospatial dataset is based on the weighted average depth to water attribute from the Soil Survey Geographic Database (SSURGO). Null values present in the SSURGO dataset were eliminated through the following procedure: 1) Delete SSURGO polygons that coincide spatially with *LARNLoad waterbodies* 2) Where null values persist, those polygons correspond to a SSURGO soil type described as having a depth to water > 80 inches (i.e. 200 cm) or a characteristic soil moisture regime of "Excessively Drained", therefore these polygons were assigned a value of 201 cm. Once completed, no null values remained, and the dataset was converted to a raster (2.5ft). The range in raw values was 0 – 201cm (Figure 4). The raw values were classified into nine ranks (Table 3 & Figure 9b) to better reflect the high amount of inorganic nitrogen attenuation that occurs in St. Lucie County within the first 100 cm of a point source while also acknowledging that inorganic nitrogen attenuation still occurs beyond the highest category represented in the SSURGO database, i.e., >200cm (Ye et al. 2023).

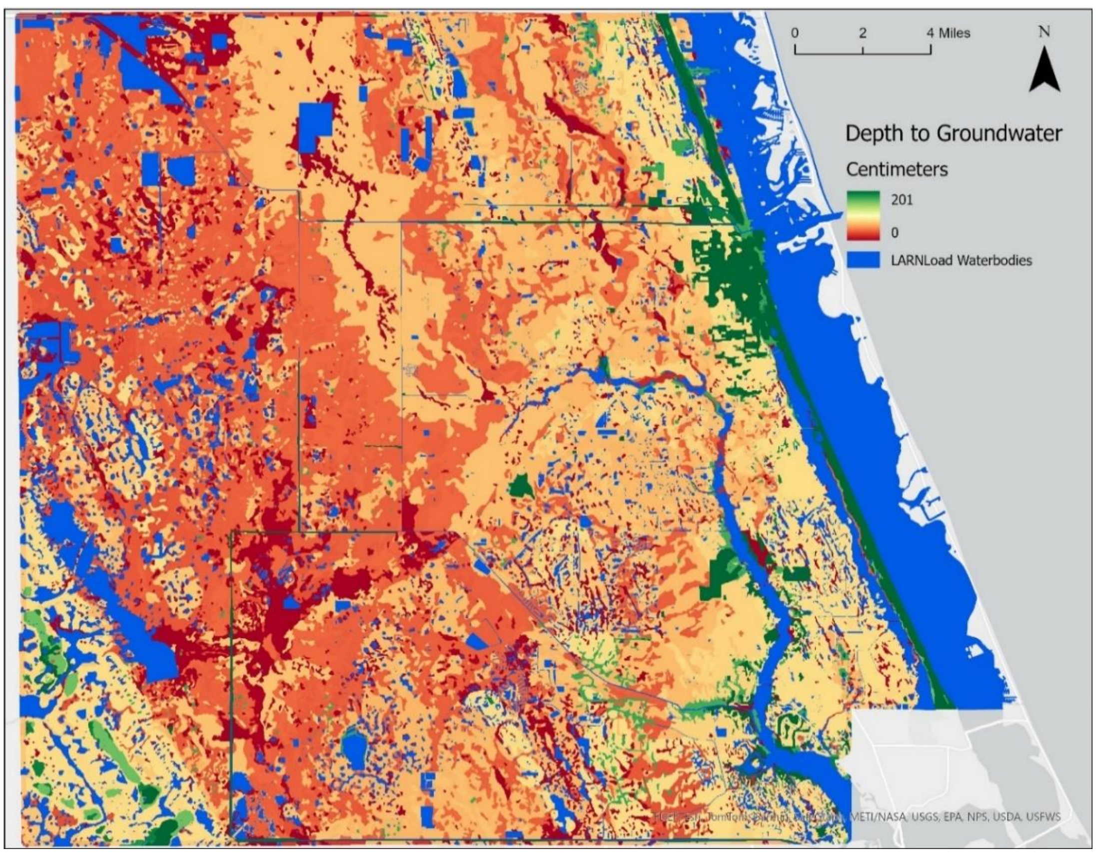

Figure 4. Depth to Groundwater in the study area

Table 3. Classification and ranks for Depth to Groundwater

Classification	Range (cm)	Rank
One interval	200+	1
One interval	100.1 – 200	2
Equal intervals	85.8 – 100.1	3
	71.5 – 85.8	4
	57.2 – 71.5	5
	42.9 – 57.2	6
	28.6 – 42.9	7
	14.3 – 28.6	8
	0 – 14.3	9

5. *Hydraulic Conductivity*

The *Hydraulic Conductivity* geospatial dataset is based on the weighted average hydraulic conductivity attribute from the Soil Survey Geographic Database (SSURGO). The SSURGO dataset assigns null hydraulic conductivity values to several locations they map as “Pits” (i.e., “open excavations” as per USDA, 2017) in the study area. However, according to recent imagery, these pits have been filled since the soil survey was conducted. The composition of the fill deposit is unknown. As a regional representative of deposit characteristics, the hydraulic conductivity value present in the adjacent polygon with the longest shared border was assigned to null “Pit” polygons. Once completed, no null values remained, and the dataset was converted to a raster (2.5ft). The range in raw values was 10.35 um/s – 244.7 um/s (Figure 5). The raw values were classified into five ranks (Table 4 & Figure 9c) established using the USDA Soil Survey Manual hydraulic conductivity classification with finer breaks in hydraulic conductivities between 10 and 100 um/s, to reflect the regional diversity of sandy soils in St. Lucie County.

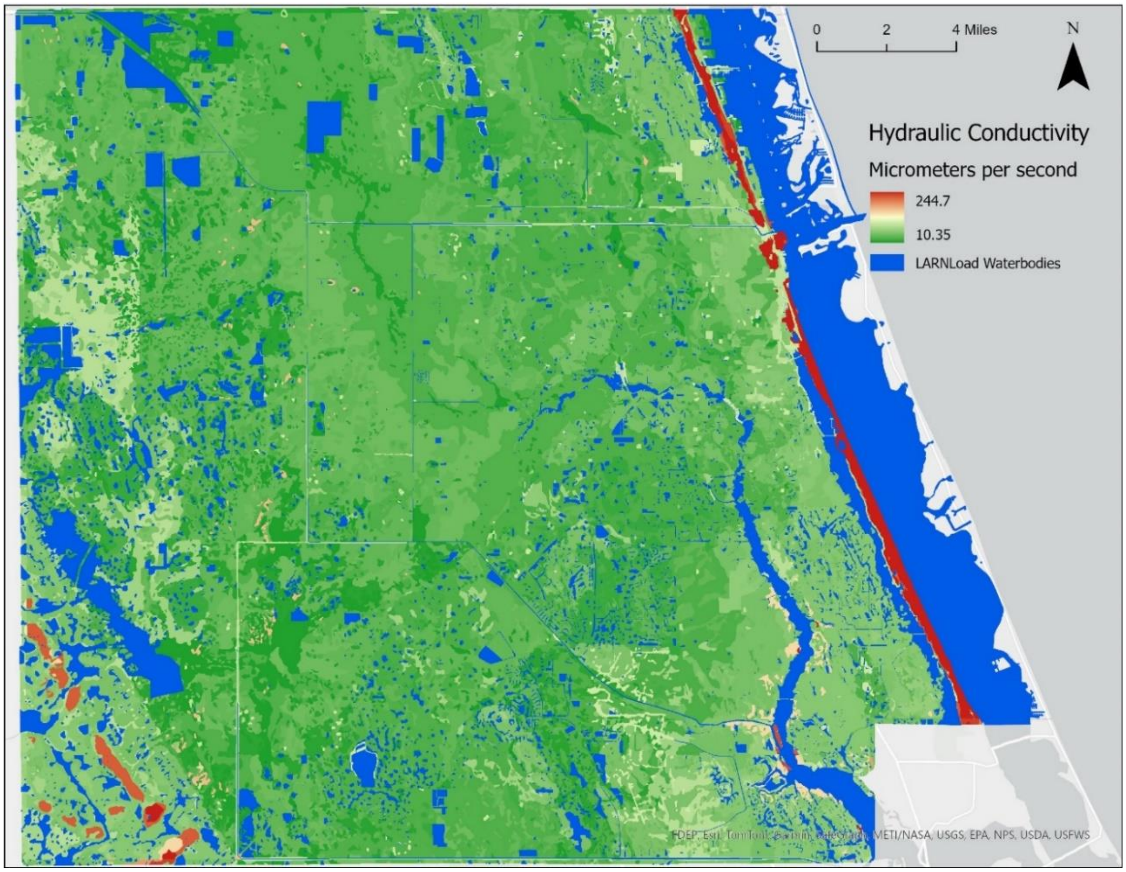

Figure 5. Hydraulic Conductivity in the study area

Table 4. Classification and ranks for Hydraulic Conductivity.

Classification	Range (µm/s)	Rank
Soil Survey Manual	< 0.01	1
	0.01 – 0.1	2
	0.1 – 1	3
	1 – 10	4
Equal intervals	10 – 25	5
	25 – 50	6
	50 – 75	7
	75 – 100	8
One interval	100+	9

6. *Potential for Flooding*

This *Potential for Flooding* geospatial dataset is based on flood zone and flood zone subtypes originating from the FEMA National Flood Hazard Layer (NFHL): X (area of minimal flooding), X (0.2% annual chance flood), AE, A, AH, VE (1% annual chance flood), and AE (regulatory floodway) (Figure 6). In the study area, the NFHL contains small slivers. To eliminate slivers, they were assigned to the adjacent polygon with the longest shared border. This dataset was converted into a raster (2.5 ft) and the NFHL categories were classified into four ranks (Table 5 & Figure 9d).

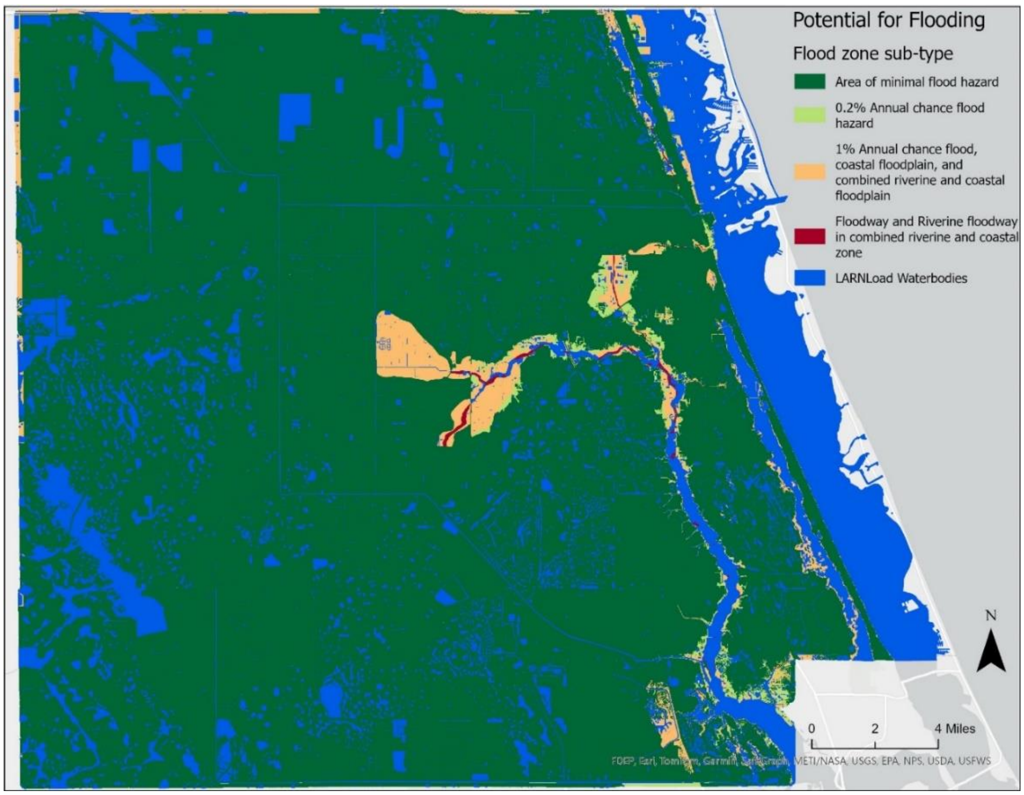

Figure 6. Potential for Flooding in the study area

Table 5. Classification and ranks for Potential for Flooding

Classification	Category	Rank
Flood zone rank definition and flood zone	FEMA flood zone X (area of minimal flooding)	1
	FEMA flood zone X (0.2% annual chance flood)	5
	FEMA flood zones AE, A, AH, VE (1% annual chance flood)	8
	FEMA flood zone AE (regulatory floodway)	9

7. *Slope*

The *Slope* geospatial dataset characterizes the change in elevation from any point in the study area to the average elevation of a natural waterbody (calculated per quarter-Township) divided by the distance from that point to the nearest waterbody (as per the *Distance to Waterbody* LARNLoad dataset). Natural waterbodies were distinguished from artificial waterbodies in *LARNLoad Waterbodies* by referencing attributes ("wetlands", "lakes", and "streams") assigned to spatially coincident water features in the *Land Cover Land Use* geospatial dataset (SFWMD, 2019). Raw elevation data were sourced from a recent digital elevation model (DEM, 2018-2020, 2.5 ft). The elevation change used in the calculation of "slope" was the difference between the DEM value at a point (2.5ft x 2.5 ft) and the average elevation summarized across all natural waterbodies within a particular quarter-Township (PLSS, BLM). Regionalizing waterbody elevations by quarter-Townships addresses concerns that regional trends in elevation will otherwise mask the small elevational differences between waterbodies and uplands. Distance data were obtained from the *Distance to Waterbody* LARNLoad dataset. The range in raw slope values was 0 – 1.55 degrees (Figure 7). The raw values were classified into nine ranks (Table 6 & Figure 9e).

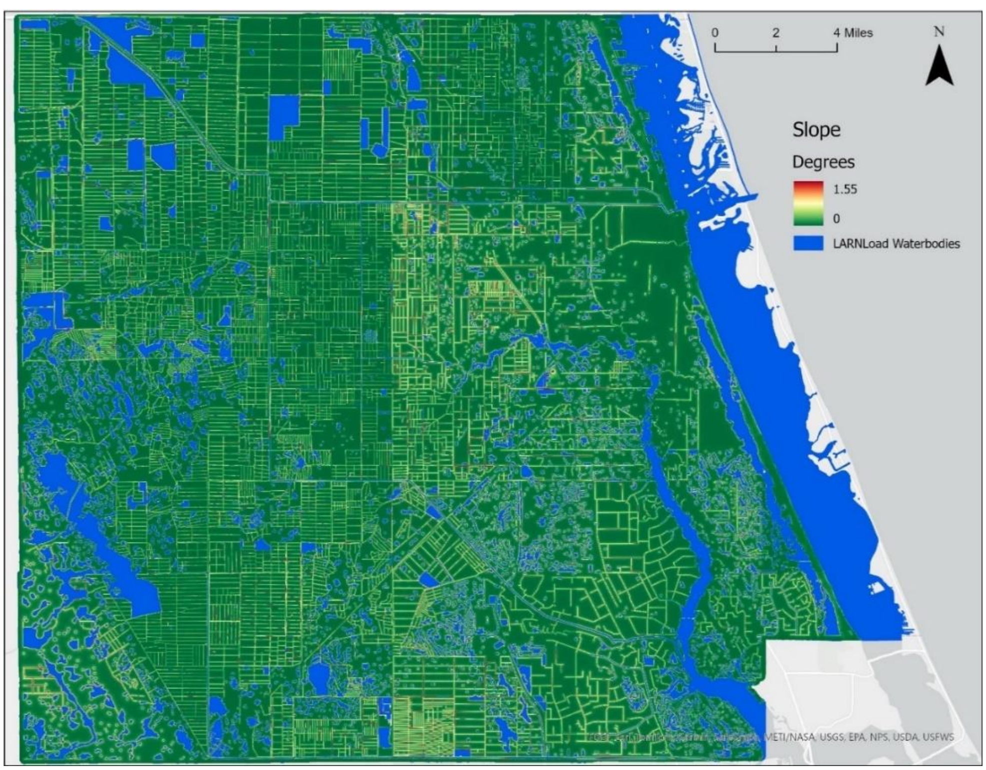

Figure 7. Slope in the study area

Table 6. Classification and ranks for Slope

Classification	Range (degrees)	Rank
Equal intervals	0	1
	0 – 0.19	2
	0.19 – 0.38	3
	0.38 – 0.57	4
	0.57 – 0.76	5
	0.76 – 0.95	6
	0.95 – 1.14	7
	1.14 – 1.33	8
	1.33 – 1.55	9

8. *Depth to Limestone*

The use of the word “depth’ in the name of this geospatial dataset implies continuous data. However, the underlying data obtained from the Surficial Geology of Florida (SGF) are categorical and the USF-ERG recommends revising the name of this parameter to “Surficial Karstic Deposit”. In SGF, *“If the shallowest occurrence of the karstic limestone is 20 feet (6.1 meters) or less below land surface, the limestone formation was mapped. If the limestone is more than 20 feet (6.1 meters) below land surface, an undifferentiated siliciclastic unit was mapped.”* (Scott, 2001). Four SGF mapping units are present in the study area: 1) limestone, coquina, sand 2) sand 3) sand, clay, organics, and 4) shells, sand, clay (Figure 8). The SGF map was converted to a raster (2.5 ft) and the four categories were classified into two ranks, based solely on the presence and properties of karstic material (Table 7 & Figure 9f). Statewide, there is a greater diversity of karstic deposits than there are in the study area. In anticipation of an in-depth analysis of this diversity that will be necessary as the model is expanded, the USF-ERG recommends avoiding the endpoint rank of “9” for this pilot study.

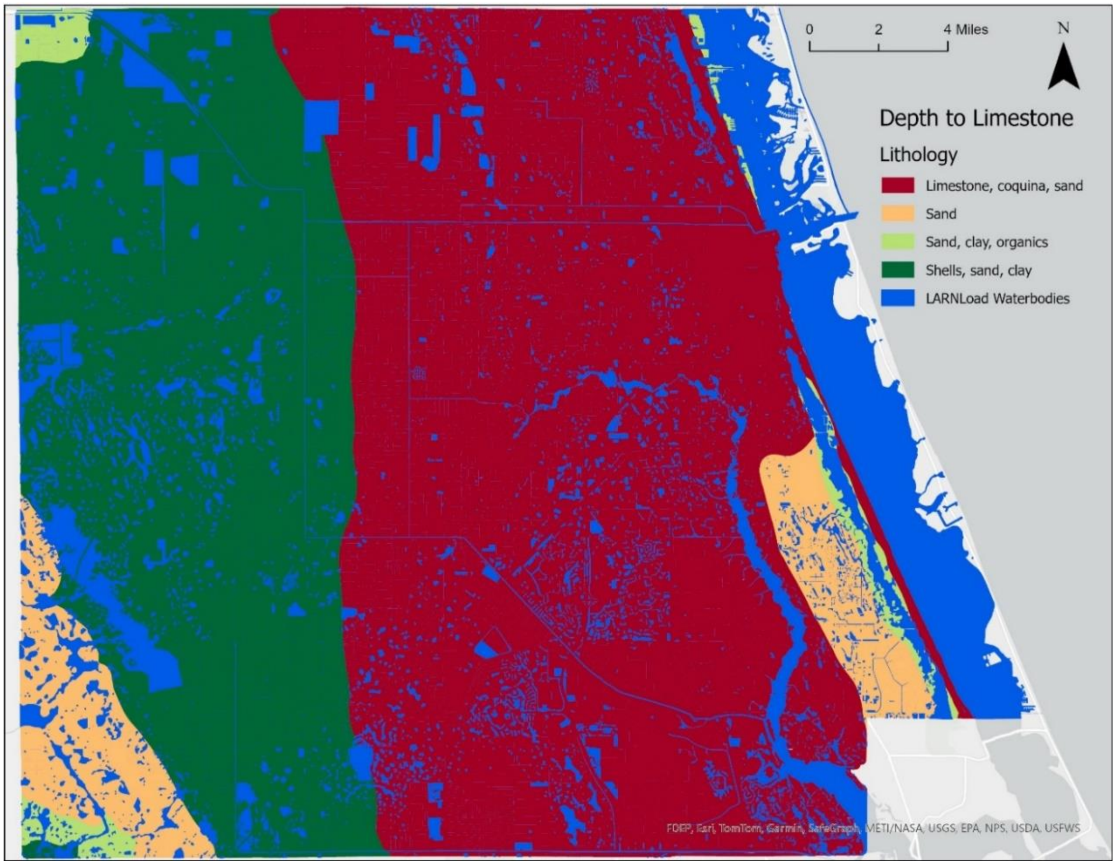

Figure 8. Depth to Limestone in the study area. The USF-ERG recommends revising this name of this parameter to "Surficial Karstic Deposit".

Table 7. Classification and ranks for Depth to Limestone

Classification method	Classification Category	Rank
Binary based on presence/absence of limestone	Sand; Sand, clay, organics; Shells, sand, clay	3
	Limestone, coquina, sand	7

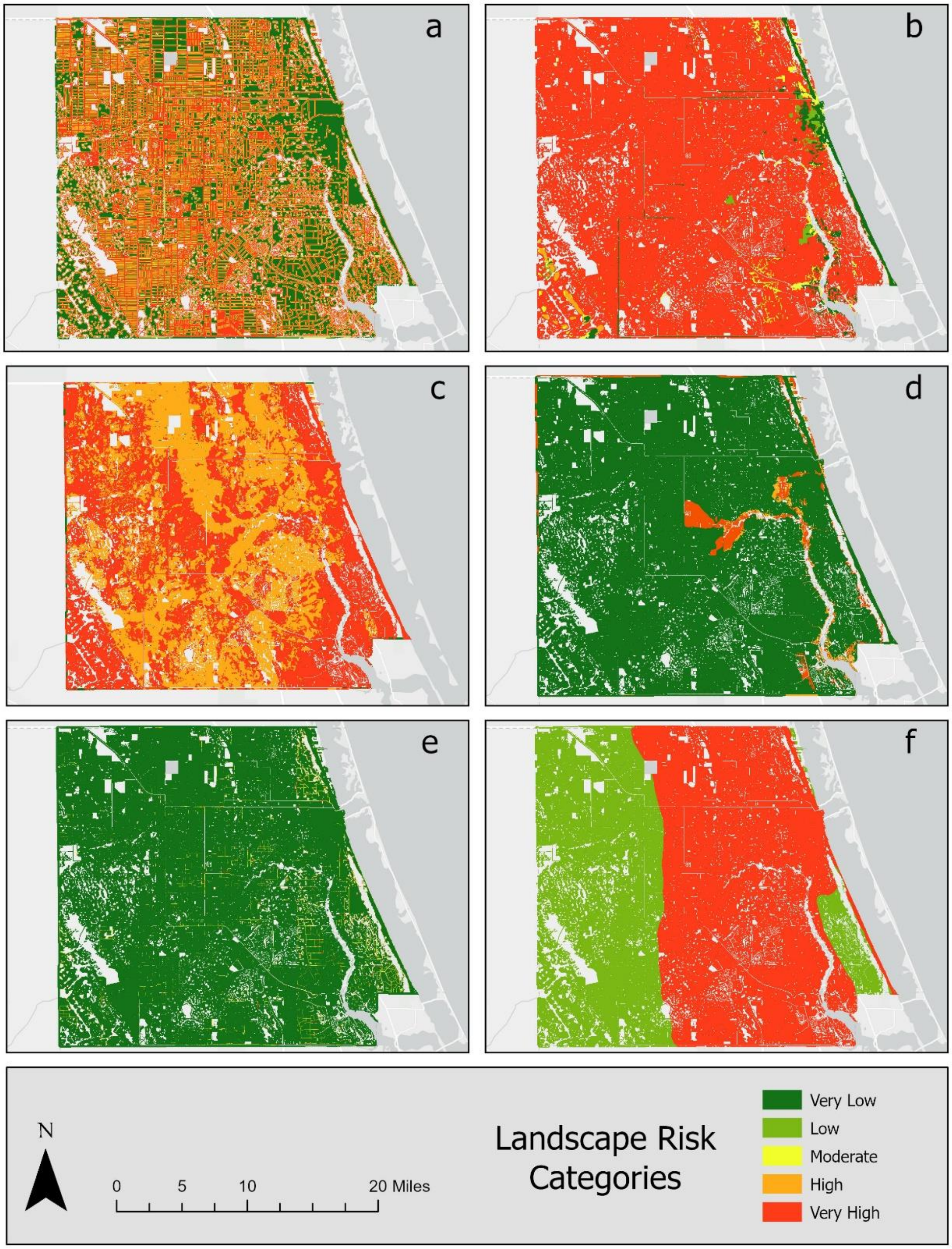

Figure 9. Distribution of landscape risk categories within geospatial datasets (a) *Distance to Waterbody*, (b) *Depth to Groundwater*, (c) *Hydraulic Conductivity*, (d) *Potential for flooding*, (e) *Slope*, and (f) *Depth to Limestone*. The raw values of each dataset were standardized into ranks and then summarized into five landscape risk categories.

9. *Evaluation "Validation" Polygons*

The locations delineated by the 30 polygons in this dataset were used to evaluate "validate" LARNLoad (Task 3) in this study area (Figure 2). The locations were selected using stratified random sampling design. The study area was stratified by Township to ensure polygons were selected county-wide. *LARNLoad map* was viewed at a scale of 1:5000 to identify contiguous sets of raster cells (minimum area was 7 square acres) classified as either very low/low risk "Lower Risk" or very high/high risk "Higher Risk". The USF-ERG delineated a minimum of one Lower Risk and one Higher Risk polygon per Township except for nine Townships which lacked sufficient contiguous Lower Risk raster cells. Fifteen Lower Risk polygons and 15 Higher Risk polygons were randomly selected from the full set at random, based on Unique ID numbers, for inclusion in a validation exercise performed blind by subject matter experts. In a separate exercise, 5 Lower Risk and 5 Higher Risk polygons were randomly selected for evaluation bysubcontractors from Florida State university using the numerical model, ArcNLET. Per polygon, physical attributes were derived from the project geodatabase. The derived attributes are: Average Distance to Waterbody (m), Average Distance to Waterbody (ft), Average Slope (degrees), Average Depth to Groundwater (cm), Average Hydraulic Conductivity (um/s), Surficial Lithology (% of Polygon area), and Flood Zone (% of polygon area).

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Appendix A. Task 1 – Geodatabase and Documentation Review and Recommendations

Pilot Scale Development of a Septic-to-Sewer Conversion Prioritization Tool Using Analytical Hierarchy Process, Phase II: Landscape Vulnerability

Task 1: Geodatabase and Documentation Review and Recommendations

DEP Agreement # AT020

For the Florida Department of Environmental Protection,

Office of Environmental Accountability and Transparency

June 2024

Prepared by The Ecohydrology Research Group

School of Geosciences

University of South Florida

Background

In a prior phase of this project, the Florida Department of Environmental Protection – Office of Environmental Accountability and Transparency (FDEP - OEAT) partnered with the University of South Florida Ecohydrology Research Group (USF-ERG) to apply the Analytical Hierarchy Process (AHP) technique for development of an Onsite Sewage Treatment Disposal Systems (OSTDS) vulnerability map for St. Lucie County (FDEP Agreement No. AT015). Six environmental parameters were identified by subject matter experts (SMEs) (FDEP Agreement No. AT006, Task 2) as most important for assessing the vulnerability of surface waters to nutrients from OSTDS. SMEs scored the relative importance of each parameter. USF-ERG synthesized and analyzed these scores to develop a model that could be implemented in GIS to generate the final product. The model and a list of suggested geospatial datasets to represent the six environmental parameters were delivered to FDEP-OEAT and converted to a geospatial product.

In Fall 2023, FDEP-OEAT staff applied the model developed as part of DEP Agreement No. AT015 to a set of geospatial datasets and determined some datasets contained omissions and/or anomalies that compromised the integrity of the end product "2023 Draft Map" and that many questions remained regarding the ranking of the data within each parameter. The model requires accurate and widely available input data. If data for any parameter in any location are inaccurate, the model will return a misleading value for that location; if data for any parameter in any location is missing, the model will return a null value for that location. The USF-ERG was awarded a grant to investigate these issues and either provide an alternative suggestion for an alternative parameter dataset or a strategy for cleansing the previously selected datasets, and to review 2023 Draft Map rankings and provide recommendations.

Of particular concern to the FDEP-OEAT were the geospatial datasets used to represent the parameters Distance to Waterbody, Hydraulic Conductivity, and Depth to Karst. Distance to Waterbody requires a definition of waterbody, especially regarding canals, which range from small and shallow (e.g., crop drainage and/or irrigation ditches) to large and deep (e.g., regional conveyance canals). Hydraulic conductivity data are acquired from Natural Resources Conservation Service Soil Survey Geographic Database (SSURGO) and should be both accurate and widely available, but there are conditions under which they could be acquired and/or applied incorrectly (e.g., null values under waterbodies). At the recommendation of the Florida Geological

Survey (FGS), Depth to Limestone was substituted by the FDEP-OEAT for Depth to Karst—the parameter originally used in the AHP—due to the lack of availability of depth to karst data.

The USF-ERG conducted a review of these and related concerns and additionally developed recommendations for classifying raw data into ranks.

Primary issues of concern addressed during Phase 2, Task 1:

1) *What guidelines should govern selection of parameter datasets?*
2) *Which features should be included as "Waterbodies"? Does the mapping provided in the NHDPlus datasets adequately reflect "waterbodies" in the study area?*
3) *The source data for two parameters, Depth to Groundwater and Hydraulic Conductivity, contains nulls. What characterizes the nulls? Should an alternate source dataset be adopted? Or can null values be populated with appropriate values?*
4) *Two parameters, Distance to Waterbody and Slope, require a point of origin. Should the point of origin be the center point of all DEM raster grid cells (2.5 ft resolution)?*
5) *What should be measured for the parameter "Slope"? Should it be the slope between any point in the study area and a waterbody? If so, will anomalies evident in the DEM (e.g., aquatic vegetation and occasional unusually high water elevations in managed canals) be problematic?*
6) *Is the Surficial Geology dataset the most appropriate dataset for "Depth to Karst" aka "Depth to Limestone"? Is this parameter named appropriately?*
7) *How should the parameter raw data be organized into the nine (or fewer) ranks required by the model?*

To address these questions, the USF-ERG reviewed project materials and additional references:

- Data and documentation provided by FDEP
  - Geospatial datasets provided by FDEP-OEAT on 2/28/2024, i.e., ranked datasets: distance to waterbody, depth to water, hydraulic conductivity, potential for flooding, slope, depth to karst, and final vulnerability map.
  - Documentation developed and prepared by FDEP-OEAT following the recommendations outlined in the final report of DEP Agreement No. AT015.
  - Email communications between FDEP-OEAT and SMEs regarding parameters raw values classification into nine ranks.
- Documentation related to data background, completeness, and ranking
  - United States Department of Agriculture Soil Survey Manual (Soil Science Division Staff, 2017).
  - Soil Survey of the St. Lucie County Area (Watts and Stankey, 1980)
  - Web Soil Survey documentation (accessed May 2024).
  - SSURGO Data and metadata (accessed May 2024)
  - *User's Guide for the National Hydrography Dataset Plus (NHDPlus) High Resolution* (Moore et al., 2019)
  - FDEP Status and Trend Network Monitoring Wells (accessed April 2024)
  - FDEP Permitting and Compliance Monitoring Wells (accessed April 2024)
  - USGS Monitoring Wells (accessed April 2024)
  - FEMA Flood Map Service Center data definitions and limitations
  - *Guidance for Flood Risk Analysis and Mapping*, Flood Insurance Rate Map (FIRM) Database (FEMA, 2023).
  - *Text to accompany the geologic map of Florida* (Scott, 2001).
  - *Estimation of Nitrogen Load from Removed Septic Systems to Surface Water Bodies in the City of Port St. Lucie, the City of Stuart, and Martin County* (Ye & Sun, 2013).
  - *ArcNLET: An ArcGIS-Based Nitrate Load Estimation Toolkit, User's Manual* (Rios et al. 2019)
  - *Technical Report of Modeling Results Analysis for Setback Distance of Onsite Sewage Treatment and Disposal Systems (OSTDS)* (Ye, et al. 2023)

There were four project meetings held between USF-ERG and the FDEP-OEAT in which Phase 2, Task 1 was the primary focus (Table A1).

Table A1. List of Phase 2, Task 1 Meeting Dates and Attendees

Meeting Date	Attendees
Feb 3, 2024	FDEP-OEAT: Julia Danyuk, Moses Okonkwo USF-ERG: Kai Rains, Edgar Guerron-Orejuela
March 7, 2024	FDEP-OEAT: Julia Danyuk, Moses Okonkwo USF-ERG: Kai Rains, Edgar Guerron-Orejuela
March 22, 2024	FDEP-OEAT: Sara Davis, Julia Danyuk, Moses Okonkwo, Mark Rains USF-ERG: Kai Rains, Edgar Guerron-Orejuela, Tyelyn Brigino, Josephina Reyman
April 1, 2024	FDEP-OEAT: Sara Davis, Julia Danyuk, Moses Okonkwo USF-ERG: Kai Rains, Edgar Guerron-Orejuela

The seven primary questions addressed in Task 1 are repeated below and followed by recommendations made by USF-ERG in consultation with the FDEP-OEAT.

Question 1) What guidelines should govern selection of parameter datasets?

Recommended Dataset Selection and Acquisition Guidelines:

1. Datasets should be acquired from primary sources. Exceptions may occur if the dataset from a secondary source has been enhanced and this enhancement would benefit the project. In all cases, the source and acquisition date should be documented.
2. Dataset set selection priorities:
    - Relevance: Datasets that reflect the parameters selected by SMEs (Phase 1, AT015).
    - Coverage: Statewide preferred over local coverage.
    - Longevity: Government sources preferred as these will likely be updated.
    - Transparency: Datasets in widespread use, publicly available, and include metadata.
3. A copy of the dataset acquired from the primary source should be retained in its original form in the Project files.

Question 2) Which features should be included as "Waterbodies"? Does the mapping provided in the NHDPlus datasets adequately reflect the distribution of waterbodies in the study area?

The waterbodies dataset is used to derive two parameters, Distance to Water and Slope. It is also instrumental in removing nulls from the geospatial datasets *Depth to Groundwater* and *Hydraulic Conductivity* and will be integrated into the model validation process (Task 3). The waterbody dataset used in the 2023 Draft Map was derived from two USGS datasets: *NHDPlus Flowlines* and *NHDPlus Waterbodies.* The USF-ERG reviewed this selection and reviewed alternative or supplemental datasets.

Recommendation:

The complete waterbodies layer used to develop the Landscape Assessment of Risk to Nutrient Loading to Waterbodies (LARNLoad) (*i.e., LARNLoad waterbodies*) should include all features in four datasets: *NHDPlus Waterbodies, NHDPlus Flowlines* (buffered on each side by 2.5 ft), *NHDPlus Area,* and *SSURGO (Water and Oceans)*.

Comments

The USF-ERG reviewed six geospatial datasets for suitability. Two, *SFWMD DBHydro* and *USF-ERG CReST*, provided complete coverage in the study area, but did not provide statewide coverage so they were not analyzed further.

The USF-ERG compared the *2023 Draft Map Waterbodies* dataset, derived from *NHDPlus Waterbodies* and *NHDPlus Flowlines,* to aerial imagery and observed that common waterbody features such as wetlands and prominent waterbodies such as large canals, the estuary, and the Indian River Lagoon, were missing. These features can be added by merging in two new datasets, *NHDPlus Area,* and *SSURGO (Water and Oceans)*.

The USF-ERG conducted two additional analyses to address concerns related to potential over-representation of canals in the fully merged dataset, *LARNLoad Waterbodies*, and to the identification of an appropriate buffer width to apply to *NHD Flowlines* to convert these features from polylines to polygons.

In a previous project funded by Federal and local agencies, the USF-ERG calculated channel density per square km across the study area (Rains et al. unpublished data). The 59 grid cells (1 km^2) with the highest channel density were selected for analysis. USF-ERG viewed channel mapping depicted in *LARNLoad Waterbodies* against aerial imagery from January, a dry season month, in 2018 and 2021. The choice of a dry season month ensured the analysis would be conservative, i.e., if channels have been over-mapped, this would be most readily apparent in the dry season. Furthermore, channels that are inundated or show signs of recent inundation during a dry season month, are included as waterbodies as per the Florida Onsite Sewage Treatment and Disposal System Regulations (FAC 381.0065(2)(m)), *"Permanent nontidal surface water body" shall also mean an artificial surface water body that does not have an impermeable bottom and side and that is designed to hold, or does hold, visible standing water for at least 180 days of the year." (i.e.,6 months)*

January 2018 was selected based on a comparison of historical precipitation data (2018-2022, Fort Pierce, FL weather station, FSU Florida Climate) against monthly 30-year normal precipitation values which revealed the region had not experienced unusually high precipitation in the months preceding January 2018 (Figure A1). January 2021 was selected as a second time period for review because it was the most recent January imagery available on Google Earth.

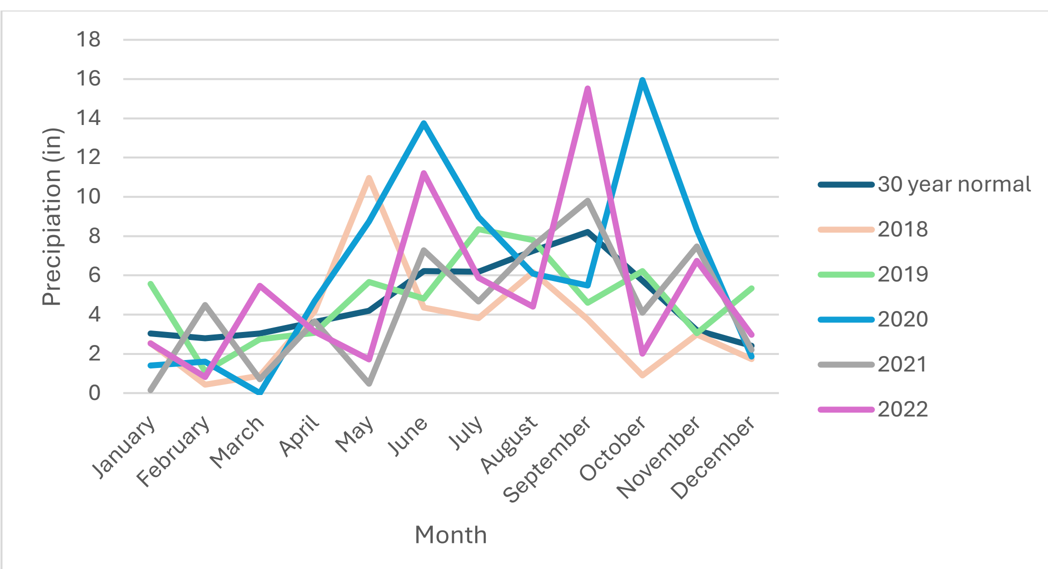

Figure A1. Comparison of historical precipitation data between 2018 and 2022 with the 30 year (1991-2020) precipitation normal for the Fort Pierce, Florida station ID USC00083207.

The USF-ERG viewed the January 2018 and 2021 Google Earth Pro aerial imagery below each mapped channel line within the 59 high channel density grid cells, measuring the length of flowlines that spatially coincided with features on the aerial imagery that did not show evidence of recent or current inundation. The total flowline length reviewed was 755 km. In both years, more than 98 percent of the flowline length coincided with features that were inundated or showed signs of recent inundation. These results support the conclusion that the *LARNLoad Waterbodies* dataset does not over-represent canals in the study area.

The USF-ERG employed a similar technique to determine an appropriate flowline buffer width, measuring channel widths evident in photo imagery in each of the 59 high channel density grid cells to determine whether there was a characteristic channel width suitable for a buffer. However, the channel widths depicted in the aerial imagery are highly variable. It was additionally noted that the *NHDPlus Flowlines* are frequently mapped at the edges of the canals, where a large buffer would likely intersect the top of adjacent levees, potentially confounding waterbody analyses. Therefore, buffering flowlines by only the minimum raster size (2.5 ft on each side), is the recommended option.

Question 3) The source data for two parameters, Depth to Groundwater and Hydraulic Conductivity, contains nulls. What characterizes the nulls? Should an alternate source dataset be adopted? Or can null values be populated with appropriate values?

The source data for the Hydraulic Conductivity and Depth to Groundwater parameters is NRCS SSURGO. This source fulfills the criteria set forth in the Guidelines for Dataset Selection and Acquisition, but the corresponding geospatial datasets contains null values in the study area. During the development of the 2023 Draft Map, FDEP-OEAT addressed null values by populating missing values with values interpolated from adjacent polygons. The USF-ERG conducted a review to evaluate those results and other options.

Recommendation

The USF-ERG recommends retaining the NRCS SSURGO as the primary source for these two parameters. The datasets can be cleansed using the procedures detailed below.

Comments

No other alternative satisfied the Project Guidelines for Selection and Acquisition of Geospatial Data (Question 1, above). Three alternative sources for *Depth to Groundwater* datasets were considered: USGS Monitoring Wells, FDEP Status and Trend Network Monitoring Wells, and FDEP Permitting and Compliance Monitoring Wells. All, however, were deemed unsuitable due either to data access or to data coverage issues.

Many of the NRCS SSURGO data gaps occur in locations where the soil survey intersects waterbodies. The USF-ERG recommends eliminating the potential impact of these nulls on model development by removing waterbodies from the weighted overlay process. Since OSTDS are not permitted in waterbodies, excluding areas intersecting waterbodies from the overlay process will not affect the study area extent over which the tool will provide meaningful risk ratings.

The USF-ERG consulted a published version of the complete text of the Soil Survey of the St. Lucie County Area (NRCS 1980) to gain insight into locations where null values for *SSURGO Hydraulic Conductivity* and *SSURGO Depth to Groundwater* intersect features other than waterbodies. This investigation revealed inconsistencies between the SSURGO Hydraulic Conductivity values accessible through web downloads and the original published data. This was reported to NRCS staff who subsequently concurred their download tool compatible with ArcGIS Pro points to the incorrect dataset. They are attempting to fix this issue. Meanwhile, they downloaded and delivered the correctly tabulated data directly to USF-ERG. In this complete dataset, there are far fewer null values. Null values in the *SSURGO Hydraulic Conductivity* and *SSURGO Depth to Groundwater* datasets that do not intersect waterbodies, are in Soil Survey Map Units classified by NRCS as “Pits” or, “Arents, 45 to 65 percent slopes”.

The Soil Survey documentation defines “Pits” as “open excavations” (USDA, 2017). However, a review of the recent aerial imagery indicates the locations mapped as Pits in the study area have been filled. The composition of the fill material is unknown, thus the USF-ERG recommends adopting a local value for these properties by populating them with values mapped in the adjacent polygon with the longest shared border.

The depth to water described in soil survey literature for “Arents 45 to 65 percent slopes” is “greater than 80 inches” and the drainage class is described as ‘Excessive’. The USF-ERG recommends assigning a Depth to Groundwater category of > 200 cm (80 in) to these polygons, thus eliminating null values.

Question 4) Two parameters, Distance to Waterbody and Slope, require a point of origin. Should the point of origin be the center point of all DEM raster grid cell (2.5 ft resolution)?

Recommendation

The analyses should be conducted at the resolution corresponding to the digital elevation model, i.e. 2.5 ft x 2.5 ft and the point of origin should be the grid cell center point.

Comments

As a pilot study, it is important to retain flexibility so a variety of end users, possibly with different constraints and project goals, can test the product. If a coarser resolution is preferred at a later stage, the raster-based product can be resampled.

Question 5) What should be measured for the parameter "Slope"? Should it be the slope between any point in the study area and a waterbody? If so, will anomalies evident in the DEM (e.g., reflecting aquatic vegetation and occasional unusually high-water elevations in managed canals) be problematic?

In the 2023 Draft Map, the FDEP-OEAT constructed a dataset representing the parameter Slope using the *FL_Peninsular_Hx_Michael_Supplemental_LiDAR* dataset (resampled to 10 m resolution) and the ArcGIS Pro slope tool. The raw values were classified into nine ranks using the Jenks Natural Breaks classification (Jenks, 1967).

Recommendation

The USF-ERG concurs the *FL_Peninsular_Hx_Michael_Supplemental_LiDAR* is the most current digital elevation model DEM for the study area and is the most appropriate dataset for the analysis for this study area.

The definition of Slope should be changed from that used in the 2023 Draft Map to one that more closely reflects an assessment of hydraulic head.

Comments

The significance of Slope as a parameter is its potential to reflect hydraulic head resulting from changes in elevations between points on the landscape and nearby waterbodies. The 2023 Draft Map was constructed using the ArcGIS Pro slope tool which calculates change between adjacent cells. A more relevant value for slope would, instead, be based on change between points on the landscape and nearby waterbodies.

The elevation value used for waterbodies should be based on a locally relevant reference that is not highly managed. The pilot study area is generally flat and managed canals, often containing aquatic vegetation, are common. In a flat landscape, small artifacts in the DEM, such as transient water elevations due to pumping, canal blockages, or aquatic vegetation can be problematic. Further issues can arise from mismatches between mapped waterbodies and the DEM. This may occur for example, if canals on the NHD products are offset and intersect the levee high points evident on the DEM rather than the low spots between levees. To avoid these issues, the USF-ERG recommends establishing reference waterbody elevations based on the average water surface elevation of natural waterbodies. These waterbodies are mapped and classified as either Natural River, Stream, Waterway, Lakes, or Wetlands in the *2017-2019 Land Use and Land Cover* dataset (South Florida Water Management District). The average elevation values of all the raster cells *(FL_Peninsular_Hx_Michael_Supplemental_LiDAR)* that intersect these waterbody polygons should be calculated at a sub-regional scale, e.g., per quarter-Township (9 mi^2) to account for local differences in elevation.

Values in the *Distance to Waterbody* dataset may be used as the denominator in the slope calculation, thus generating a slope value between every 2.5 ft raster cell and the nearest waterbody.

Question 6) Is the Surficial Geology dataset the most appropriate dataset for "Depth to Karst" aka "Depth to Limestone"? Is this parameter named appropriately?

The parameter Depth to Karst was selected by SMEs in 2023 (AT015) as the sixth landscape factor to include in this pilot project. However, the geospatial data corresponding to depth values are not available, and the *Surficial Geology of Florida* geospatial dataset was proposed by the Florida Geological Survey as a potential substitute.

Recommendation

The USF-ERG confirms this selection fulfills the Recommended Dataset Selection and Acquisition Guidelines (Question 1, above) and is the most appropriate geospatial dataset available. Although the dataset does not include depth to limestone, it does report the presence of limestone if it is likely to occur within 20 ft of the ground surface, i.e., *"If the shallowest occurrence of the karstic limestone is 20 feet (6.1 meters) or less below land surface, the limestone formation was mapped. If the limestone is more than 20 feet (6.1 meters) below land surface, an undifferentiated siliciclastic unit was mapped"* (Scott 2001).

Comments

The name of the parameter was changed during Phase I (AT015) from "Depth to Karst" to "Depth to Limestone" to reflect the categorical nature of this dataset. However, USF-ERG recommends again changing the name of this parameter in Phase 3 due to the following two concerns: The term "depth" implies continuous data while the raw data in the *Surficial Geology of Florida* are categorical. A second type of karstic deposit, dolostone, is mapped outside the pilot project area but within Florida. If this study is expanded in Phase 3 to regions containing dolostone, a more inclusive name for this parameter would be "Surficial Karstic Deposit".

Question 7) How should the parameter raw data be organized into the nine (or fewer) ranks required by the model?

Once parameter datasets have been identified, the raw data within each dataset is standardized by classifying it into nine or fewer groups ranked by "contribution to risk" from 1 (lowest contribution) to 9 (highest contribution). These classification groups are called "ranks". The USF-ERG reviewed the ranks established by FDEP-OEAT to generate the 2023 Draft Map to determine whether changes to the ranking system were advisable. Certain aspects of this investigation will be developed in greater detail in Task 2, Sensitivity Analysis (Final Report, Appendix B) and are additionally defined in the LARNLoad metadata (Final Report, Appendix F). However, the general recommendations are summarized in parts A- F, below.

Question 7, Part A) Classification and Ranking of Distance to Waterbody

2023 Draft Map

In the 2023 Draft Map, Distance to Waterbody values were defined as the distance to waterbodies included only in the *NHD Waterbodies* and *NHD Flowlines* datasets. Multi-ring buffer polygons were established around the waterbodies: 0 - 100m, 10m increments; 100 - 1500m, 50m increments; with a maximum distance of 1,500m. Polygons were rasterized (resolution, 10m) and reclassified according to Table A2. below.

Table A2. Distance to Waterbody classification and ranks as they appeared in the 2023 Draft Map

Classification Range (m)	Rank
> 200	1
51 – 200	5
0 - 50	9

Recommendations for Ranking Distance to Water

As detailed above, the USF-ERG recommends waterbody features from two additional geospatial dataset sources be used to develop a more comprehensive *Waterbody* dataset.

The USF-ERG additionally recommends Distance to Waterbody calculations be made on a raster basis rather than a polygon basis. This approach will streamline the process and reduce the amount of data manipulation required.

The USF-ERG further recommends the ranks defined in the *Distance to Waterbody* dataset be revised to better reflect ArcNLET modeling results. Those results indicate that although much of the inorganic nitrogen originating from a point source in St. Lucie County sands is attenuated within the first 100 m, elevated concentrations will be present up to 200 m and, depending on soil type, beyond 200 m (Ye et al. 2023). Recommendations for a revised ranking system are presented in Table A3.

Table A3. Recommended classification and ranks for Distance to Waterbody raw values

Classification	Range (m)	Rank
One interval	199.95+	1
One interval	99.97 – 199.95	2
Equal intervals between 0 and 100 m	85.59 – 99.97	3
	71.32 – 85.59	4
	57.06 – 71.32	5
	42.80 – 57.06	6
	28.53 – 42.80	7
	14.02 – 28.53	8
	0.76 – 14.02	9

Question 7, Part B) Classification and Ranking Depth to Groundwater

<u>Recommendations for Ranking Depth to Groundwater:</u>

The USF-ERG recommends the ranks defined in the *Depth to Groundwater* dataset be revised to better reflect ArcNLET modeling results. This modeling indicates a high amount of the inorganic nitrogen attenuation likely occurs in St. Lucie County within 100 cm of a point source but may be incomplete even up to the highest category represented in the SSURGO database, i.e., > 200cm. beyond the point source. Suggested revisions to the classification and ranking system are depicted in Table A4.

Table A4. Recommended classification and ranks for Depth to Groundwater

Classification	Range (cm)	Rank
One interval	200+	1
One interval	100.1 – 200	2
Equal intervals between 0 and 100 m	85.8 – 100.1	3
	71.5 – 85.8	4
	57.2 – 71.5	5
	42.9 – 57.2	6
	28.6 – 42.9	7
	14.3 – 28.6	8
	0 – 14.3	9

Question 7, Part C) Classification and Ranking of Hydraulic Conductivity

In the USDA Soil Survey Manual, hydraulic conductivity is classified by value into six different classes (Table A5).

Table A5. Saturated Hydraulic Conductivity classification (NRCS Staff, 2017).

Class	Hydraulic Conductivity (μm/s)
Very high	≥ 100
High	10 to < 100
Moderately high	1 to < 10
Moderately low	0.1 to < 1
Low	0.01 to < 0.1
Very low	< 0.01

<u>Recommendations for Ranking Hydraulic Conductivity:</u>

The USF-ERG recommends the ranks defined in the Hydraulic Conductivity dataset be revised to better reflect the classification used by the USDA Soil Survey (Table A6) yet also include additional subdivisions in the range of 10 to < 100 um/s to reflect the regional diversity of sandy soils in St. Lucie County.

Table A6. Recommended classification and ranks for Hydraulic Conductivity

Classification	Range (um/s)	Rank
Soil Survey	< 0.01	1
	0.01 – 0.1	2
	0.1 – 1	3
	1 – 10	4
Equal intervals from 10 to 100 um/s	10 – 25	5
	25 – 50	6
	50 – 75	7
	75 – 100	8
One interval	100+	9

Question 7, Part D) Classification and Ranking of Potential for Flooding

<u>2023 Draft Map</u>

The *Potential for Flooding* dataset in the 2023 Draft Map was derived from the *National Flood Hazard Layer* (NFHL) created by the Federal Emergency Management Agency (FEMA). The raw values were classified into four ranks (Table A7) and the FEMA Flood Zone X “area of minimal flooding” was assigned to the lowest risk rank of “3”.

Table A7. Potential for Flooding classification and ranks as they appeared in the 2023 Draft Map

Classification	Rank
Area of minimal flooding	3
0.2% Annual chance of flood	5
1% Annual chance of flood	8
Regulatory Floodway	9

<u>Recommendations for Ranking Potential for Flooding</u>

The USF-Erg recommends re-classifying the FEMA Flood Zone X to distinguish between the two distinct subtypes contained within this zone, i.e., “area of minimal flooding” and “0.2% annual chance flood”. The FEMA Flood Zone X (area of minimal flooding) is the lowest flood zone classification defined by FEMA; therefore, the USF-ERG further recommends assigning the lowest risk rank (i.e., 1) to this classification category (Table A8).

Table A8. Recommended classification and ranks for Potential for Flooding

Classification	Classification Category	Rank
Flood zone rank definition and flood zone	FEMA flood zone X (area of minimal flooding)	1
	FEMA flood zone X (0.2% annual chance flood)	5
	FEMA flood zones AE, A, AH, VE (1% annual chance flood)	8
	FEMA flood zone AE (regulatory floodway)	9

Question 7, Part E) Classification and Ranking of Slope

2023 Draft Map

In the 2023 Draft Map, the raw data for the parameter Slope was based on changes in elevation between adjacent grid cells (10 m^2) and sorted into ranks using Jenks Natural Breaks (Jenks, 1967). In the Jenks Natural Breaks system, raw data is organized into groups that minimize within-group variance while maximizing between-group variance. Previously the USF-ERG utilized Jenks Natural Breaks successfully to create a regional map of groundwater recharge and suggested this as a potential option early in model development (Guerron-Orejuela et al. 2023). The FDEP—OEAT adopted this approach to develop the 2023 Draft Map.

Recommendations for Ranking Slope

For reasons detailed in the response to Questions 5 above, the USF-ERG recommends slope values be recalculated to reflect the change in elevation from raster cells to an elevation representative of local natural waterbodies divided by the distance to the nearest waterbody.

Furthermore, due, in part, to the increased likelihood this pilot study will be expanded outside the study area, the USF-ERG recommends an interval system for ranking (Table A9).

Table A9. Recommended classification and ranks for Slope

Classification method	Classification Range (degrees)	Rank
Equal intervals	0	1
	0 – 0.19	2
	0.19 – 0.38	3
	0.38 – 0.57	4
	0.57 – 0.76	5
	0.76 – 0.95	6
	0.95 – 1.14	7
	1.14 – 1.33	8
	1.33 – 1.55	9

Question 7, Part F) Classification and Ranking of Depth to Limestone

<u>2023 Draft Map</u>

In the 2023 Draft Map, Depth to Limestone was based on a categorical dataset, the *Surficial of Geology.* The polygons in that dataset were converted into a raster (10 m) and the values were classified and ranked as outlined in Table A10.

Table A10. Depth to Limestone classification and ranks as they appeared in the 2023 Draft Map

Classification	Rank
Shells, sand, clay	2
Sand, clay, organics	5
Sand	9
Limestone, coquina, sand	9

<u>Recommendations for Ranking Depth to Limestone</u>

The USF-ERG noted in a review of FDEP-OEAT communication with SMEs, that the question posed to the SME was confounding hydraulic conductivity and limestone which led to the rank of 9 to be assigned to the non-karstic deposit, sand. Since hydraulic conductivity is included in the model as an independent parameter and the initial question posed to SMEs when choosing and evaluating this model was based on karst properties alone, the USF-ERG recommends retaining ranking Depth to Limestone solely on the presence and properties of karstic material.

Statewide, there is a greater diversity of karstic deposits than there are in the study area. In anticipation of the in-depth analysis that will be necessary as the model is expanded, the USF-ERG recommends avoiding the endpoint rank of “9” for this pilot study (Table A11).

Table A11. Recommended classification and ranks for Depth to Limestone

<table>
<tr><th>Classification</th><th>Category</th><th>Rank</th></tr>
<tr><td rowspan="2">Binary based on presence/absence of limestone</td><td>Sand; Sand, clay, organics; Shells, sand, clay</td><td>3</td></tr>
<tr><td>Limestone, coquina, sand</td><td>7</td></tr>
</table>

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Appendix B. Task 2 – Sensitivity Analysis

Pilot Scale Development of a Septic-to-Sewer Conversion Prioritization Tool Using Analytical Hierarchy Process, Phase II: Landscape Vulnerability

Task 2: Sensitivity Analyses

DEP Agreement # AT020

For the Florida Department of Environmental Protection,

Office of Environmental Accountability and Transparency

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Introduction

This document includes the methods and results of a series of sensitivity analyses (Phase 2, Task 2, DEP Agreement AT020) conducted to assess model responsiveness to changes in model settings. The model can be used to assess landscape vulnerability to Onsite Sewage Treatment and Disposal Systems (OSTDS) in the pilot study area, St. Lucie County, FL.

At the conclusion of Phase 1 of this project (DEP Agreement AT015, FY22-23), the USF-ERG identified geospatial datasets to reflect the six model parameters. In Fall 2023, FDEP-OEAT staff acquired early versions of those datasets and developed classification methods and ranks to create a model "2023 Draft Map". In Phase 2, Task 1 (DEP Agreement AT020), the USF-ERG evaluated the 2023 Draft Map model inputs, updated the geospatial datasets, and, in collaboration with FDEP-OEAT, developed the updated input settings reflected in Tables B1 and B2. The updated model is called the Landscape Assessment of Risk to Nutrient Loading to Waterbodies (LARNLoad).

In the present task, Task 2, we report the methods and results of targeted sensitivity analyses designed to address key questions identified by the University of South Florida Ecohydrology Research Group (USF-ERG) and the Florida Department of Environmental Protection Office of Environmental Accountability and Transparency (FDEP-OEAT).

Sensitivity analyses provide insight into the interactions between model inputs and outputs. The user institutes systematic changes while monitoring output response, revealing the relative importance of individual model inputs or model settings. LARNLoad inputs and settings include six physical landscape parameters, the relative weights assigned to those parameters, the raw data values, the method (e.g., equal intervals, natural breaks, manual intervals) used to classify the raw values within each of the six parameters into nine ranks (Table B1), the ranking hierarchy (e.g., low to high, high to low), and the method by which the nine ranks were consolidated into five final Landscape Risk categories, i.e., Very High, High, Moderate, Low, Very Low (Table B2).

Table B1. Summary of baseline (i.e., unaltered) LARNLoad input settings and the crosswalk between raw values and corresponding ranks.

Parameter (weight)	**Classification Method**	**Raw value range**	**Rank**
Distance to Waterbody (30%)	One interval	199.95+	1
	One interval	99.97 – 199.95	2
	Equal intervals	85.59 – 99.97	3
		71.32 – 85.59	4
		57.06 – 71.32	5
		42.80 – 57.06	6
		28.53 – 42.80	7
		14.02 – 28.53	8
		0.76 – 14.02	9
Depth to Groundwater (21.6%)	One interval	200+	1
	One interval	100.1 – 200	2
	Equal intervals	85.8 – 100.1	3
		71.5 – 85.8	4
		57.2 – 71.5	5
		42.9 – 57.2	6
		28.6 – 42.9	7
		14.3 – 28.6	8
		0 – 14.3	9
Hydraulic Conductivity (20.7%)	Soil Survey	< 0.01	1
		0.01 – 0.1	2
		0.1 – 1	3
		1 – 10	4
	Equal intervals	10 – 25	5
		25 – 50	6
		50 – 75	7
		75 – 100	8
	One interval	100+	9
Potential for Flooding (10.9%)	Flood zone rank definition and flood zone	Area of Minimal Flooding	1
		0.2% Annual chance Flood	5
		1% Annual Chance Flood	8
		Regulatory floodway	9
Slope (9.8%)	Equal intervals	0	1
		0 – 0.19	2
		0.19 – 0.38	3
		0.38 – 0.57	4
		0.57 – 0.76	5
		0.76 – 0.95	6
		0.95 – 1.14	7
		1.14 – 1.33	8
		1.33 – 1.55	9

Depth to Limestone (7.0%)	One interval	Sand; Sand, clay, organics; Shells, sand, clay	3
	One interval	Limestone, coquina, sand	7

Table B2. Baseline (i.e., unaltered) LARNLoad ranks and Landscape Risk categories

LARNLoad scale	
Rank	**Landscape Risk categories**
1	Very Low
2	
3	Low
4	Moderate
5	High
6	
7	Very High
8	
9	

__**Overview of Sensitivity Analyses, Lines of Inquiry:**__

1. **Effect of Parameter Weights**

   How sensitive is the model output to variations in parameter weights? In LARNLoad, the weight assigned to each parameter signifies its relative importance in contributing to nutrient loading to waterbodies. In Phase 1, the Analytical Hierarchy Process (AHP) was employed to determine the appropriate weight for each of the six physical landscape parameters. In Task 2, we performed sensitivity analyses to evaluate the model's response to changes in parameter weights under two different scenarios:

   a. Unequal vs Equal Parameter Weights: How sensitive is the model to departures from a baseline condition in which all parameters are weighted equally?

   b. Altering Unequal Parameter Weights: How sensitive is the model to changes in the weight assigned to the parameter *Depth to Limestone*? This parameter was ranked as lowest in importance by Subject Matter Experts (SMEs) for this pilot project study area (study area). Yet, it may increase in importance if LARNLoad is applied elsewhere (e.g., in the springs region of Florida). How does the pilot study model output change if the *Depth to Limestone* parameter is assigned a weight similar to that of highly weighted parameters, i.e. *Hydraulic Conductivity* and *Distance to Waterbody*?

2. **Raw Data Classification for Ranking**.

   Before parameters can be combined into a single model, the raw data within each parameter must be converted to a uniform classification system. How sensitive is the model output to variations in classification method for ranking? In LARNLoad, this system contains nine "ranks", though not every rank must be populated. We conducted a series of analyses to investigate the sensitivity of model outputs to modifications to the methods used to classify raw data by making modifications to a) the method used to classify raw values into ranks and b) the rank definitions.

   a. <u>Ranking Method (Natural Breaks vs Intervals)</u>: What is the effect of using Jenks Natural Breaks (Jenks, 1967) versus an Interval method (equal intervals versus custom intervals) to assign raw data to ranks? Natural Breaks is based on the distribution of the data to identify points where the data can be split into different classes with minimal within-class variance, while the interval method relies on the numerical values of the data. How sensitive is the model to the selection of ranking method?

   b. <u>Raw Data within Ranks</u>

   i. Continuous Data: How sensitive is the model to changes in the range of raw values of continuous data within ranks?

   1. *Slope* Parameter: The distribution of slope raw values in the study area is bimodal and highly right- skewed, i.e., there is a very high frequency of low values, few moderate values, and an intermediate frequency of high values. What is the effect on the model output of establishing ranks containing unequal ranges of data, i.e., ranks containing smaller ranges in raw values at the low end and high ranges at the high end?

2. *Distance to Waterbody* Parameter: In Phase I, SMEs assigned the highest weight, i.e. 30 %, to this parameter. Thus, changes to this parameter are expected to have the most impact on the model output. How sensitive is the model output to changes in the raw values ranges for the parameter *Distance to Waterbody*?

ii. Categorical Data:

1. *Depth to Limestone* Parameter: How sensitive is the model to changes in the distribution of categorical data across ranks? The *Depth to Limestone* parameter is based on a surficial geology categorical dataset. Only four of the 20 Florida surficial geology deposits occur in the study site and only one of those includes limestone. How sensitive is the model to changes in the distribution of these four categories across the nine ranks?

Methods

The method selected to explore each of these questions was tailored to the specific question posed. This approach provided key insights into the aspects of LARNLoad which the USF-ERG and FDEP-OEAT identified jointly as being of concern. An alternative approach, described in the Task 2 scope of this agreement, outlined the procedure for a one-at-a-time (OAT) sensitivity analysis, altering each parameter weight individually and monitoring response at a series of randomly chosen points. We deviated from this simplistic approach for three primary reasons. First, an OAT sensitivity requires varying each input individually while keeping others constant. However, this procedure would violate a structural requirement of LARNLoad and the AHP methodology used in its development. In AHP, the weights of all parameters must sum to 100%, such if one parameter weight is adjusted, another must be adjusted to ensure the sum of the weights is 100. Parameter weights cannot be adjusted "one at a time". Second, while monitoring output at randomly chosen points is a statistically valid approach to analysis, monitoring the effect across the complete study area provides a more comprehensive result, thus we opted for the latter approach. Third, the questions posed by USF-ERG and FDEP-OEAT during Task 1 extended beyond the level of parameter weights to also include the effect of ranking methods, thus increasing the breadth of the sensitivity analysis. We employed additional parameter weight and ranking sensitivity analyses, technically outside the scope of this agreement, to better address the intent of Task 2, i.e., to gain insight into the interactions between model inputs and model outputs. Note that an additional series of Sensitivity Analyses could have been performed to gauge the transportability of LARNLoad to other regions, i.e., changes to the raw data. This was also outside of the current scope of this agreement and will, by default, be tested once the model is expanded to new regions.

1. Effect of Parameter Weights, Methods

We designed two sensitivity analyses to investigate the effect of parameter weights on the LARNLoad outputs. In both we ensured the sum of the parameter weights was 100%, the ranking of raw values, and the ranking classification into risk categories remained unchanged (see Tables B1 and B2).

a. Unequal vs Equal Parameter Weights

To test the interactions among the six parameters in our model, we assigned equal weight values to all parameters (Figure B1). By doing so, we ensured that each parameter contributed equally to the overall model, allowing us to observe their combined effects without bias towards any single parameter. This model is called "LARNLoad Equal Weights".

Distance to Waterbody	⇒	16.67%
Depth to Water	⇒	16.67%
Hydraulic Conductivity	⇒	16.67%
Potential for Flooding	⇒	16.67%
Slope	⇒	16.67%
Depth to Limestone	⇒	16.67%

Figure B1. Modified weights for the LARNLoad Equal Weights Sensitivity Analysis.

b. Altering Unequal Parameter Weights

We subtracted 2.35 percentage points from each parameter, then added the total of these subtracted points, 11.75 percentage points, to the depth to limestone parameter (Figure B2). This specific adjustment was selected to ensure that the depth to limestone parameter would be weighted like that of the four highest-weighted parameters. This allowed us to test the model's behavior when a parameter with a low weight in LARNLoad, i.e., Depth to Limestone, was attributed a higher weight. After these modifications, we reran the model to observe the effects. This model is called "LARNLoad Depth to Limestone weight modified".

Distance to Waterbody	⇒	30%	-	2.35%	=	27.65%
Depth to Water	⇒	21.6%	-	2.35%	=	19.25%
Hydraulic Conductivity	⇒	20.7%	-	2.35%	=	18.35%
Potential for Flooding	⇒	10.9%	-	2.35%	=	8.55%
Slope	⇒	9.8%	-	2.35%	=	7.45%
Depth to Limestone	⇒	7.0%	+	11.75%	=	18.75%

Figure B2. Modified weight calculation to attribute a potential higher weight to the parameter *Depth to Limestone* while maintaining the sum of all parameter weights at 100%

We compared the relative proportion of the study area assigned to the nine ranks and to the five risk categories for the modified and unaltered model runs.

2. Raw Data Classification for Ranking, Methods

In LARNLoad, it is essential to assign appropriate weights to each parameter and to standardize the raw data within each parameter. We conducted a series of analyses using both continuous and categorical data to investigate the sensitivity of model outputs.

a. Ranking Method (Natural Breaks vs Intervals): We ran two iterations of the LARNLoad model to test the effect of the choice of ranking method on the model results. In the initial iteration, the raw values for all four parameters with continuous raw values were classified into ranks using the Jenks natural breaks classification, while those with categorical data were unchanged from the unaltered LARNLoad model. This model is referred to as "LARNLoad Natural Breaks". In the second iteration, the raw values for all four parameters with continuous raw values were classified into ranks using equal intervals, while those with categorical data were unchanged from the unaltered LARNLoad model. This model is referred to as "LARNLoad Equal Intervals".

b. Raw Data within Ranks

i. Continuous Data

1. *Slope* Parameter: Our study area exhibits a predominantly flat landscape, resulting in a distribution of slope data skewed toward lower values, with most of the slope differences being emphasized in areas adjacent to canals. We tested the effect of changing the definition of the ranks to more finely distinguish differences in the lower slope values.

LARNLoad Slope modification 1: Slope values of 0 degrees were assigned to a unique rank (rank = 1), slope values between 0 and 1 degrees, were split into seven equal intervals, and slope values above 1 degree were grouped into a single rank (rank = 9) (Table B3).

LARNLoad Slope modification 2: Slope values of 0 degrees were assigned to a unique rank (rank = 1), slope values between 0 and 0.5 degrees were split into six equal intervals, slope values between 0.5 and 1 degree were assigned to rank 8, and slope values between 1 and 1.55 degrees were assigned to rank 9 (Table B3).

Table B3. Highest raw data values for ranks 1-9 in Unaltered LARNLoad and LARNLoad *Slope* modifications 1 and 2.

Rank	**Unaltered *Slope* (degrees)**	***Slope* modification 1 (degrees)**	***Slope* modification 2 (degrees)**
1	0	0	0
2	0.19	0.142	0.0833
3	0.38	0.285	0.167
4	0.57	0.427	0.250
5	0.76	0.569	0.333
6	0.95	0.711	0.417
7	1.14	0.853	0.5
8	1.33	0.995	1
9	1.55	1.55	1.55

2. *Distance to Waterbody* Parameter: We tested the effect of three different methods of defining ranks for a highly weighted variable, Distance to Waterbody: natural breaks equal intervals, and the classification method used to develop the 2023 Draft Map (Table B4). LARNLoad was run four times, once for each test.

Table B4. The ranking definitions used in the 2023 Draft Map for the Parameter, Distance to Waterbody. These definitions were included as one variant in the "Raw Data within Ranks, Continuous Data, Distance to Waterbody" analysis

Definition (m)	**Rank**
0-50	9
51 – 200	5
>200	1

ii. Categorical Data

1. *Depth to Limestone* Parameter: The intent of this parameter is to capture the presence and characteristics of karstic deposits. In the study area, there is only one type of karstic deposit described. We compared the results of the unaltered LARNLoad model to the results obtained when the Depth to Limestone rank definitions were as per the 2023 Draft Map (Table B5).

Table B5. The ranking definitions used in the 2023 Draft Map for the Parameter, Depth to Limestone. These definitions were included as on variant in the "Raw Data within Ranks, Categorical Data" analysis

Definition	Rank
Limestone, coquina, sand	9
Sand	9
Sand, clay, organics	5
Shells, sand, clay	2

Results

1. Effect of Parameter Weights, Results

a. Unequal vs Equal Parameter Weights

When LARNLoad parameters were all assigned equal weights, the rank of two was no longer populated (Table B6). In addition, the relative percentage of the study area classified as Moderate Risk increased while that classified as High Risk decreased (Table B6).

Table B6. Comparison of the distribution of study area by risk category and rank resulting from the models, unaltered LARNLoad and LARNLoad Equal Weights.

		Unaltered	**Equal Weights**
Risk Categories	**Rank**	**Area (% of total)**	**Area (% of total)**
Very Low	1	NA	NA
	2	3E-04	NA
Low	3	1.8	1.7
Moderate	4	27	41
High	5	30.5	48
	6	35.2	8.3
Very High	7	5.4	0.7
	8	0.2	0.03
	9	5E-04	1.77E-05

b. Altering Unequal Parameter Weights

When the weight (i.e., importance) of the parameter Depth to Limestone was increased, the percentage of the study area assigned to the moderate risk category decreased while the percentage assigned to the high-risk category increased (Table B7, Figure B3). Furthermore, the ranks of two and nine were no longer populated.

Table B7. Comparison of the distribution of study area by risk category and rank resulting from the models, unaltered LARNLoad and LARNLoad Depth to Limestone parameter weight altered.

		Unaltered	***Depth to Limestone* weight modified**
Risk Category	**Rank**	**Area (% of total)**	**Area (% of total)**
Very Low	1	NA	NA
	2	3E-04	NA
Low	3	1.8	0.8
Moderate	4	27	18.7
High	5	30.5	38.4
	6	35.2	34.1
Very High	7	5.4	7.9
	8	0.2	0.1
	9	5E-04	NA

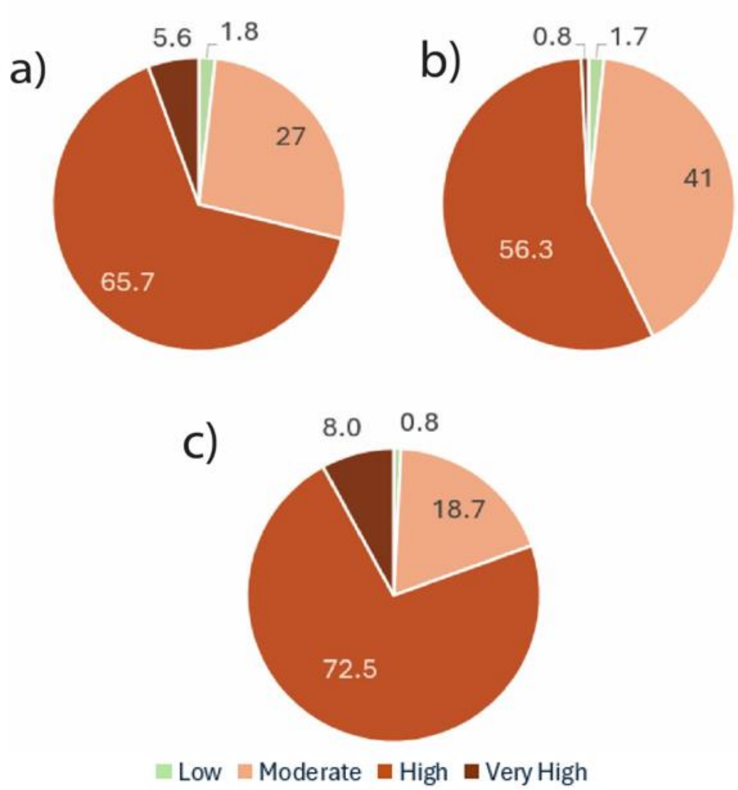

Figure B3. Comparison of the proportion of the study area across the five risk categories using the LARNLoad models: a) unaltered, b) Equal Weights, and c) Depth to Limestone weight modified model. The numbers in the figure represent percentage of total area. Areas with values less than 0.5% are not distinguishable in this Figure. For details see Table B7.

2. Raw Data Ranges for Ranking, Results

a. Ranking Method (Natural Breaks vs Intervals):

In the unaltered LARNLoad model, the greatest proportion of total study area is concentrated in ranks 5 and 6. In contrast, in the LARNLoad Natural Breaks model the greatest amount of total study area is concentrated in ranks 4 and 5. The LARNLoad Equal Intervals model results in a very different distribution, with 88% of the study area assigned to rank 5 (Table B8). This in turn changes the relative proportion of the study area assigned to risk ratings. There is a shift to lower risk ratings when natural breaks was used and a shift to the risk rating of "High" when equal intervals was used (Table B8, Figure B4).

These results highlight the strong effect the classification method can have of the distribution of the study area across risk categories.

Table B8. Comparison of the distribution of study area by risk category and rank resulting from three models: unaltered LARNLoad, LARNLoad based on natural breaks, and LARNLoad based on equal intervals

		Unaltered	Natural Breaks	Equal Intervals
Risk Category	**Rank**	**Area (% of total)**	**Area (% of total)**	**Area (% of total)**
Very Low	1	NA	1.04E-05	NA
	2	3E-04	0.5	0.08
Low	3	1.8	5.6	0.6
Moderate	4	27	43.7	6.2
High	5	30.5	47.7	88.9
	6	35.2	2.4	4.2
Very High	7	5.4	1.57E-05	2.87E-05
	8	0.2	NA	NA
	9	5E-04	NA	NA

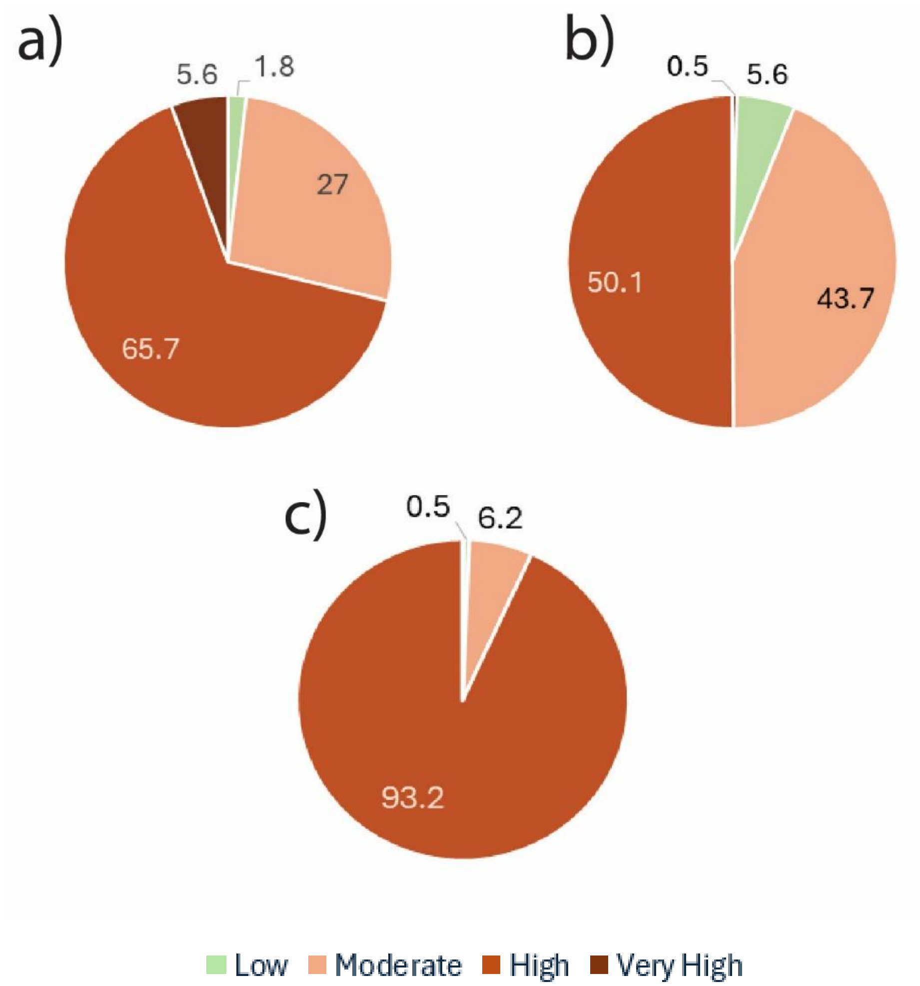

Figure B4. Comparison of the proportion of the study area across the five risk categories using the LARNLoad models: a) unaltered model, b) Natural Breaks model, and c) Equal Intervals model. The numbers in the figure represent percentage of total area. Areas with values less than 0.5% are not distinguishable in this Figure. For details see Table B8.

b. Raw Data within Ranks

i. Continuous Data

1. *Slope Parameter*:

When the definitions of the ranks used for slope were altered to increase the number of divisions in the lower end of the slope values and decrease the number of divisions in the higher end, there were no changes to the number of populated ranks (Table B9).

Both modifications resulted in an increase in the proportion of the study area assigned to Rank 7 and a decrease in the proportion assigned to Rank 6. This change had the effect of increasing the proportion of the study area rated as Very High Risk (Table B9, Figure B5). Decreasing the threshold at which equal intervals began, from 1 degree in Modification 1 to 0.5 degrees in Modification 2, increased the proportion of the study area designated as Very High Risk.

Table B9. Comparison of the distribution of study area by risk category and rank resulting from three models: unaltered LARNLoad, Slope modification 1, and Slope modification 2

		Unaltered	***Slope* modification 1**	***Slope* modification 2**
Risk Category	**Rank**	**Area (% of total)**	**Area (% of total)**	**Area (% of total)**
Very Low	1	NA	NA	NA
	2	3E-04	3E-04	3E-04
Low	3	1.8	1.7	1.7
Moderate	4	27	25.7	25.6
High	5	30.5	30.8	30.3
	6	35.2	31.4	28.9
Very High	7	5.4	10	13
	8	0.2	0.4	0.5
	9	5E-04	3E-03	3E-03

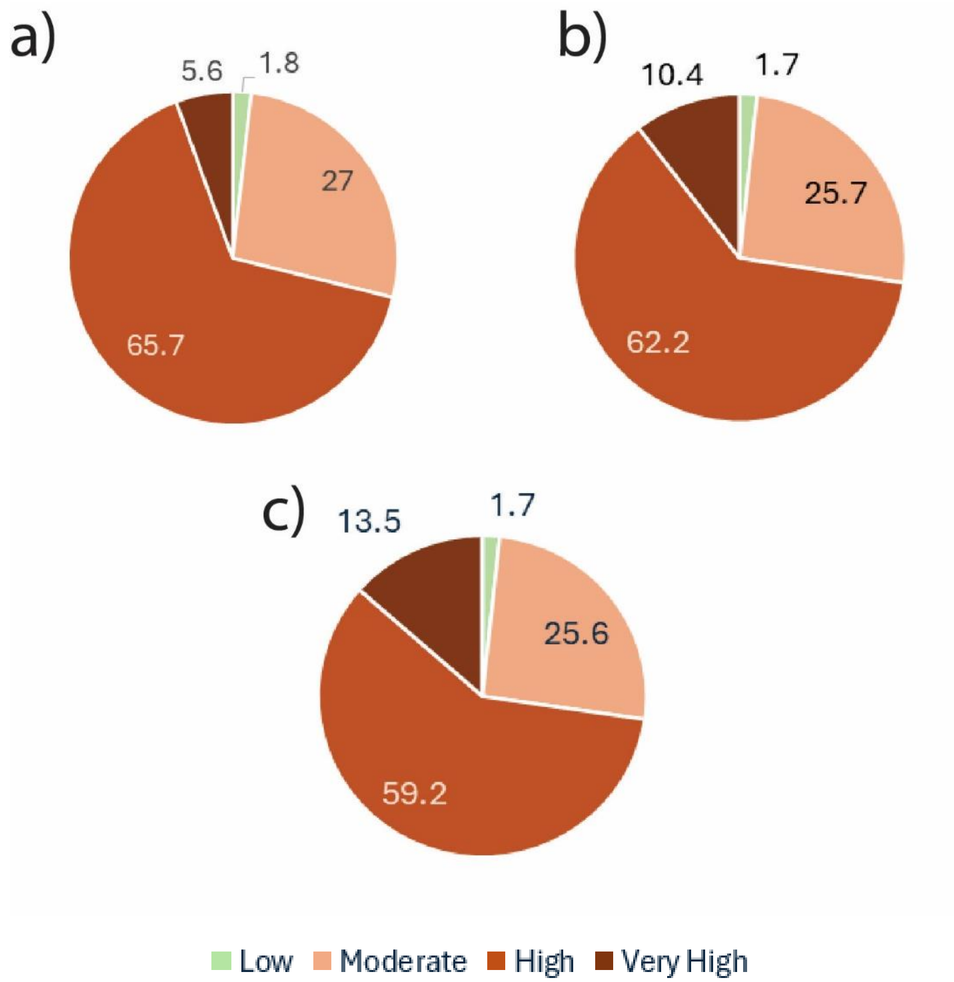

Figure B5. Comparison of the proportion of the study area across the five risk categories using the LARNLoad models: a) unaltered, b) Slope modification 1, c) Slope modification 2. In Slope modification 1 and 2 the rank ranges were modified to more finely separate among low slope values. The numbers in the figure represent percentage of total area. Areas with values less than 0.5% are not distinguishable in this Figure. For details see Table B9.

2. *Distance to Waterbody* Parameter:

We evaluated three different settings for LARNLoad by modifying the classification method for converting Distance to Water raw values to ranks. The methods tested were natural breaks, equal intervals, and the 2023 Draft Map definitions for ranks.

In the unaltered LARNLoad model, most of the area falls into ranks 4-6. When the natural breaks or equal intervals methods for defining the ranks are used, there is an increase in the proportion of the study area assigned to higher ranks and to the higher risk classes. In contrast, when the ranks are defined as per the 2023 Draft Map, there is a substantial shift to the lower ranks and an increase in the proportion of the study area lower risk ratings (Table B10).

These results highlight that the method of classifying a highly weighted parameter such as the Distance to Waterbody greatly impacts the distribution of land risk categories, with natural breaks and equal intervals methods skewing the distribution towards higher risk categories, while the 2023 Draft Map method distributes the study area predominantly into lower risk categories (Figure B6).

Table B10. Comparison of the distribution of study area by risk category and rank resulting from four models: unaltered LARNLoad, and modified *Distance to Waterbody* Parameter ranks defined by natural breaks, equal intervals, and as per the 2023 Draft Map

		Unaltered	***Distance to Waterbody* (Natural Breaks)**	***Distance to Waterbody* (Equal Intervals)**	***Distance to Waterbody* (2023 Draft Map)**
Risk Category	**Rank**	**Area (% of total)**	**Area (% of total)**	**Area (% of total)**	**Area (% of total)**
Very Low	1	NA	NA	NA	1.9
	2	3E-04	NA	NA	52.3
Low	3	1.8	0.3	0.05	32.7
Moderate	4	27	1.8	0.4	12.9
High	5	30.5	16.8	3.2	0.2
	6	35.2	65.7	70.8	NA
Very High	7	5.4	15	25	NA
	8	0.2	0.4	0.5	NA
	9	5E-04	6E-04	6E-04	NA

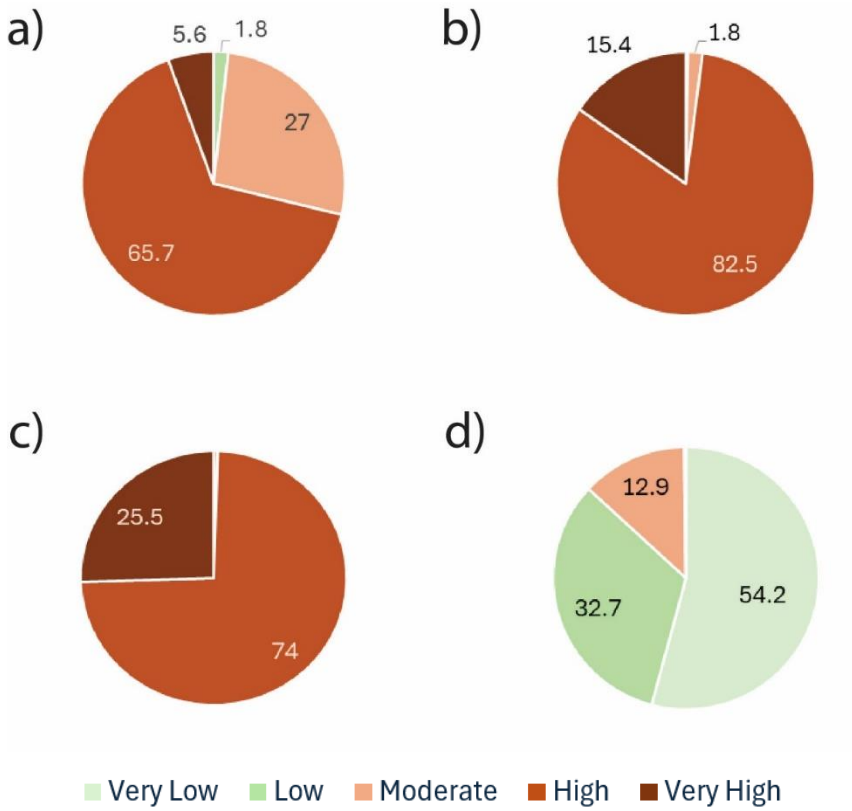

Figure B6. Comparison of the proportion of the study area across the five risk categories using the LARNLoad models: a) unaltered model, b) Distance to Waterbody (natural breaks), c) Distance to Waterbody (equal intervals), and d) Distance to Waterbody (2023 Draft Map). The numbers in the figure represent percentage of total area. Areas with values less than 0.5% are not distinguishable in this Figure. For details see Table B10.

ii. Categorical Data:

1. *Depth to Limestone* parameter

In the unaltered LARNLoad model, ranks 4-6 account for the highest proportion of the study area. When the definitions used in the 2023 Draft map are used for the Depth to Limestone parameter, the proportion of study area designated as Very Hgh Risk doubles (Table B11, Figure B7).

Table B11. Comparison of the distribution of study area by risk category and rank resulting from the unaltered LARNLoad model and from the LARNLoad *Depth to Limestone* modified rank model.

		Unaltered	**LARNLoad *Depth to Limestone* modified rank**
Risk Category	**Rank**	**Area (% of total)**	**Area (% of total)**
Very Low	1	NA	NA
	2	3E-04	NA
Low	3	1.8	1.05
Moderate	4	27	22.4
High	5	30.5	32.4
	6	35.2	32.2
Very High	7	5.4	11.5
	8	0.2	0.47
	9	5E-04	2E-03

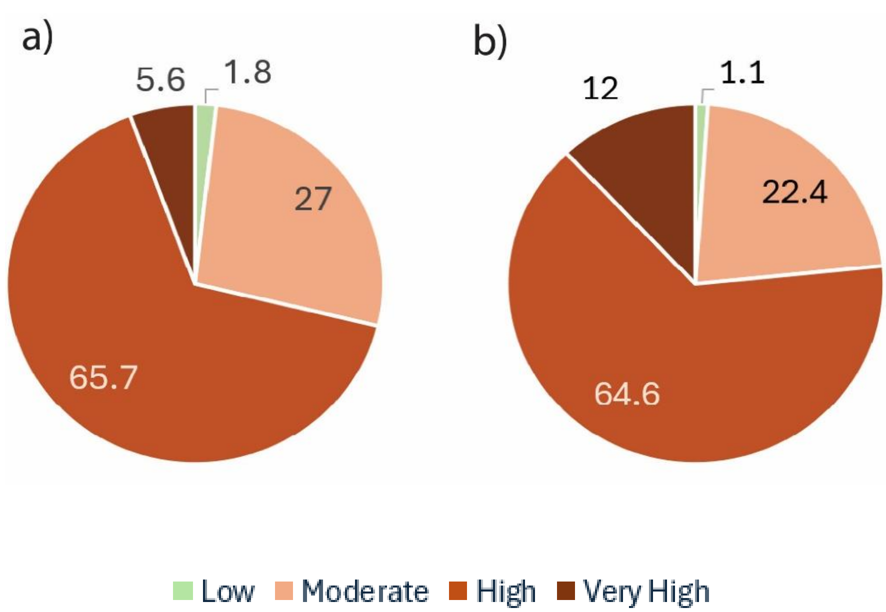

Figure B7. Comparison of the proportion of the study area across the five risk categories using the LARNLoad models: a) the unaltered model, and b) the Depth to Limestone modified rank model. The numbers in the figure represent % of total area. Areas with values less than 0.5% are not distinguishable in this Figure. For details see Table B11.

Discussion

Changes to model parameter settings resulted in shifts in data across ranks and affected the distribution of the risk categories across the study area. These results are unsurprising, given that one of the fundamental settings of the model is the weight attributed to each parameter. These results underscore the importance of the process chosen to define the parameters and set their weights. For LARNLoad, parameter weights were determined through SME participation in an exercise utilizing Analytical Hierarchy Process (AHP) and resulting in parameter weight selections exhibiting a high degree of internal consistency.

Similarly, changes to model inputs related to ranks resulted in shifts in data across ranks and affected the distribution of the risk classes across the study area, although the direction and magnitude of response differed by analysis. The results of these sensitivity analyses provide insight to the model in the pilot study area but should be interpreted with caution if the model is applied to new regions. The raw data in a new region will change the sensitivity of the model to changes in other inputs. For example, the highest rank applied to karstic deposits in the pilot study area was a seven. If this model is applied to a region with more erodible karstic deposits and regions are attributed a rank of nine for the parameter currently called “Depth to Limestone”, then the model will react differently to changes in the weight of that parameter.

Overall, the sensitivity analysis demonstrates that the model is appropriately responsive to adjustments in weights and ranks within the pilot study area, indicating a robust and reliable framework. The model reacted in predictable ways to changes in the input settings. The consistent model behavior in response to modifications indicates it will provide reliable insights into the risk to waterbodies of nutrient addition in the pilot study area.

References

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Appendix C. Task 3 – Validation

Pilot Scale Development of a Septic-to-Sewer Conversion Prioritization Tool Using Analytical Hierarchy Process, Phase II: Landscape Vulnerability

Task 3: Validation

DEP Agreement # AT020

For the Florida Department of Environmental Protection,

Office of Environmental Accountability and Transparency

June 2024

Prepared by The Ecohydrology Research Group

School of Geosciences

University of South Florida

Overview

The USF-ERG assessed the performance of, i.e., "validated", the Landscape Assessment of Risk to Nutrient Loading to Waterbodies (i.e., LARNLoad, formerly known as the "OSTDS Vulnerability Tool") by comparing the risk categories assigned by LARNLoad at locations within the study area to those predicted by two independent methods, subcontractor assessment based on modeled groundwater nutrient loading (ArcNLET) and subject matter expert (SME) assessment based on best professional judgement. For both, the USF-ERG pre-selected polygons for evaluation from the LARNLoad map using a stratified random sampling design. Both the subcontractors and SMEs assigned relative risk categories to evaluation polygons blindly, i.e., without knowledge of the risk category assigned by LARNLoad.

In the first approach, "ArcNLET Comparison", Dr Ming Ye (Florida State University, sub-contractor) modeled groundwater nutrient loading using ArcNLET from 120 point locations designated as Onsite Sewage Treatment and Disposal System (OSTDS) effluent sources (12 locations within each of 10 evaluation polygons). ArcNLET was developed previously by Dr Ming Ye and collaborators specifically to estimate nitrate loads to surface waterbodies from OSTDS. In this exercise, his team aggregated ArcNLET results by polygon to assign a relative risk category (Higher vs. Lower) to each polygon where the terms "higher risk" and lower risk" refer to the relative risk of nutrient loading to waterbodies if OSTDS effluent was released at these locations.

In the second approach, "Subject Matter Expert Comparison", USF-ERG compared the relative risk categories assigned by LARNLoad to those assigned by project subject matter experts (SMEs). Project SMEs are professionals from private, government, and academic sectors who were selected previously to participate in the Analytical Hierarchy Process workshop (DEP Agreement AT015) to select and rank the LARNLoad parameters.

Methods

Polygon delineation

The USF-ERG delineated polygons from the LARNLoad map of the study area and selected subsets for evaluation, "evaluation polygons", using a stratified random sampling design. The study area was first stratified by Township to ensure polygons were delineated and selected county-wide. During delineation, LARNLoad was viewed at a scale of 1:5000 to identify contiguous sets of raster cells (7 acres) classified as either very low/low risk, which were called “Lower Risk” for the purposes of this validation, or very high/high risk, which were called “Higher Risk” for the purposes of this validation. USF-ERG delineated a minimum of one Lower Risk and one Higher Risk polygon per Township except for nine Townships which lacked sufficient contiguous raster cells to form Lower Risk polygons at least 7 acres in size. Polygons were randomly selected by ID number for evaluation. Five Lower Risk and five Higher Risk polygons were evaluated using ArcNLET and 15 Lower Risk polygons and 15 Higher Risk polygons were evaluated by project SMEs (Figure C1).

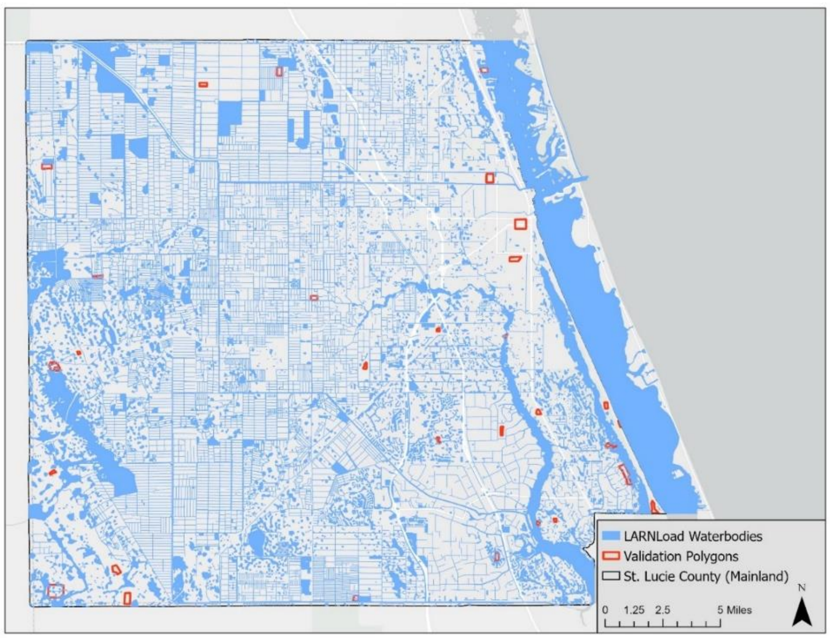


Figure C1. The distribution of polygons used to validate LARNLoad. These polygons are referred to as “evaluation polygons” in the text.

ArcNLET Comparison

ArcNLET is a GIS-based Nitrate Load Estimation Toolkit and is designed to simulate nitrate transport from OSTDS in groundwater and estimate nitrate loading from OSTDS to waterbodies (Mao et al., 2024; Rios et al., 2013). Florida State University (FSU) researchers, Dr. Ming Ye and Dr. Wei Mao, used ArcNLET to model nutrient loads to waterbodies from point sources within ten polygons, i.e., five Lower Risk and five Higher Risk polygons. Their analysis was conducted blind, i.e., they were not informed which polygons had been categorized by LARNLoad to be Lower Risk or Higher Risk.

Although both LARNLoad and ArcNLET are geospatial tools, they have different input requirements. Point source locations are necessary to run ArcNLET. For this exercise, point source locations were established within each polygon using ArcGIS. The USF-ERG created a fishnet of points reflective of the housing density of a typical suburban neighborhood in St. Lucie County. The FSU team selected “fictitious” point source locations within evaluation polygons from this fishnet. For polygons with regular shapes (n = 3), they selected 12 equidistant points per polygon (Figure C1). For polygons with irregular shapes (n = 7), they selected 12 points per polygon using a random sampling procedure. They ran ArcNLET at these 120 locations (i.e., 12 locations per polygon) to quantify the nutrient loads intersecting waterbodies and then aggregated the results by polygon. They used these results to categorize five of the 10 polygons to a “Higher Risk” category and five to a “Lower Risk” category.

Both ArcNLET and LARNLoad require geospatial input waterbody datasets. However, the source of these datasets differs. The FSU subcontractors use the NHD layer from the Florida Geographic Data Library as input for ArcNLET, while LARNLoad utilizes a merged dataset derived from the NHDPlus HR layer sourced directly from USGS and the SSURGO dataset from NRCS. During this exercise, the FSU subcontractors determined there were waterbodies missing from their waterbody input layer in two of the 10 validation polygons that were evident on aerial imagery. They hand-digitized these missing waterbodies, as per standard ArcNLET procedures (Table C2).

ArcNLET typically is run using a 10 m resolution, but standard ArcNLET procedures allow modelers to change the resolution of the input datasets as needed. During this exercise, the FSU subcontractors determined resampling at a finer resolution was necessary in a single polygon (#7). They resampled this polygon to a 1 m resolution to more accurately capture the presence of a canal.

Subject Matter Expert Comparison

Project SMEs assessed the relative risk of nutrient loading to waterbodies at 30 polygons using a relative scale, i.e., Higher Risk vs Lower Risk. The seven participating project SMEs represented academia, private industry, and state and local agencies (Table C1). During their assessment (June 2024), SMEs did not have access to the LARNLoad map but were provided access to an interactive map (Survey 123) developed in collaboration with FDEP-OEAT that included the polygon locations, geospatial datasets representing the six LARNLoad parameters, and a summary of the polygon landscape attributes (i.e., average distance to waterbody, average depth to water, average hydraulic conductivity, flood zones summarized by percentage area of polygon, average slope to nearest waterbody, and lithology summarized by percentage area of polygon) (Appendices D and E).

Table C1. Participants (Subject Matter Experts) in the LARNLoad SME Validation, alphabetical by last name.

Subject Matter Expert	Affiliation
Alan Baker	State Government
Lauren Campbell	State Government
Roxanne Groover	Industry
Sam Hankinson	State Government
Brian Ingram	Local Government
Mark Rains	Academia
Eb Roeder	State Government

SMEs were instructed to:

1. Use the information provided on the Survey 123 platform to review the landscape properties of each of the 30 evaluation polygons.
2. Sort the 30 evaluation polygons into two categories based on the relative risk that a uniform amount of nutrients added to soils (as if from OSTDS effluent) at these locations would pose to waterbodies, 15 Higher Risk polygons and 15 Lower Risk polygons.
3. Categorize the evaluation polygons strictly on physical properties of the landscape, not on the current presence/absence of potential nutrient sources
4. Record and submit their answers using Survey 123.

Results

ArcNLET Comparison

ArcNLET results predict OSTDS effluent released at the evaluation polygons would vary from a daily load of 0 – 26.005 g of total inorganic N to nearby waterbodies (Table C2). These results were strongly influenced by the proximity of nutrient sources to waterbodies. When a potential nutrient source is located near a surface waterbody, the likelihood of the plumes reaching the surface waterbodies with a higher nutrient load increase (Figure C2). There was an 80% agreement between the risk categories assigned by the FSU contractors based on ArcNLET results and those assigned by LARNLoad (Table C2).

Table C2. Nutrient loading to waterbodies modeled by ArcNLET from 120-point source locations aggregated by polygon (12 locations within each polygon) and the relative risk category assigned by ArcNLET subcontractors (FSU) and by LARNLoad (USF-ERG). Note the designation of higher risk vs lower risk is reflective only of the *relative* risk of nutrient loading to waterbodies. For example, these results suggest only that OSTDS effluent at polygon # 25 would pose greater risk to waterbodies than OSTDS effluent at polygon #26. These designations do NOT imply the authors consider the modeled daily nutrient load at polygon #26 to be inherently low risk.

Polygon Unique ID	# Nutrient load source locations	# of Plumes that reach a waterbody	NH4-N (g/day)	NO3-N (g/day)	NH4-N + NO3-N (g/day)	ArcNLET Rank	LARNLoad Rank
2	12	0	0	0	0	Lower	Lower
3	12	6	3.433	1.047	4.48	Higher	Lower
7*	12	11	9.029	16.976	26.005	Higher	Higher
8**	12	12	10.093	5.467	15.56	Higher	Higher
11	12	11	0.089	0.828	0.917	Higher	Higher
14	12	0	0	0	0	Lower	Lower
18	12	0	0	0	0	Lower	Lower
25	12	11	0.103	0.686	0.789	Higher	Higher
26**	12	2	0.002	0.099	0.101	Lower	Lower
29	12	3	0.021	0.115	0.136	Lower	Higher

* ArcNLET analysis was conducted using a modified DEM resolution of 1m to better detect small canals within the area of interest, as per standard ArcNLET procedures.

** FSU researchers manually digitized missing waterbodies in these polygons, as per standard ArcNLET procedures

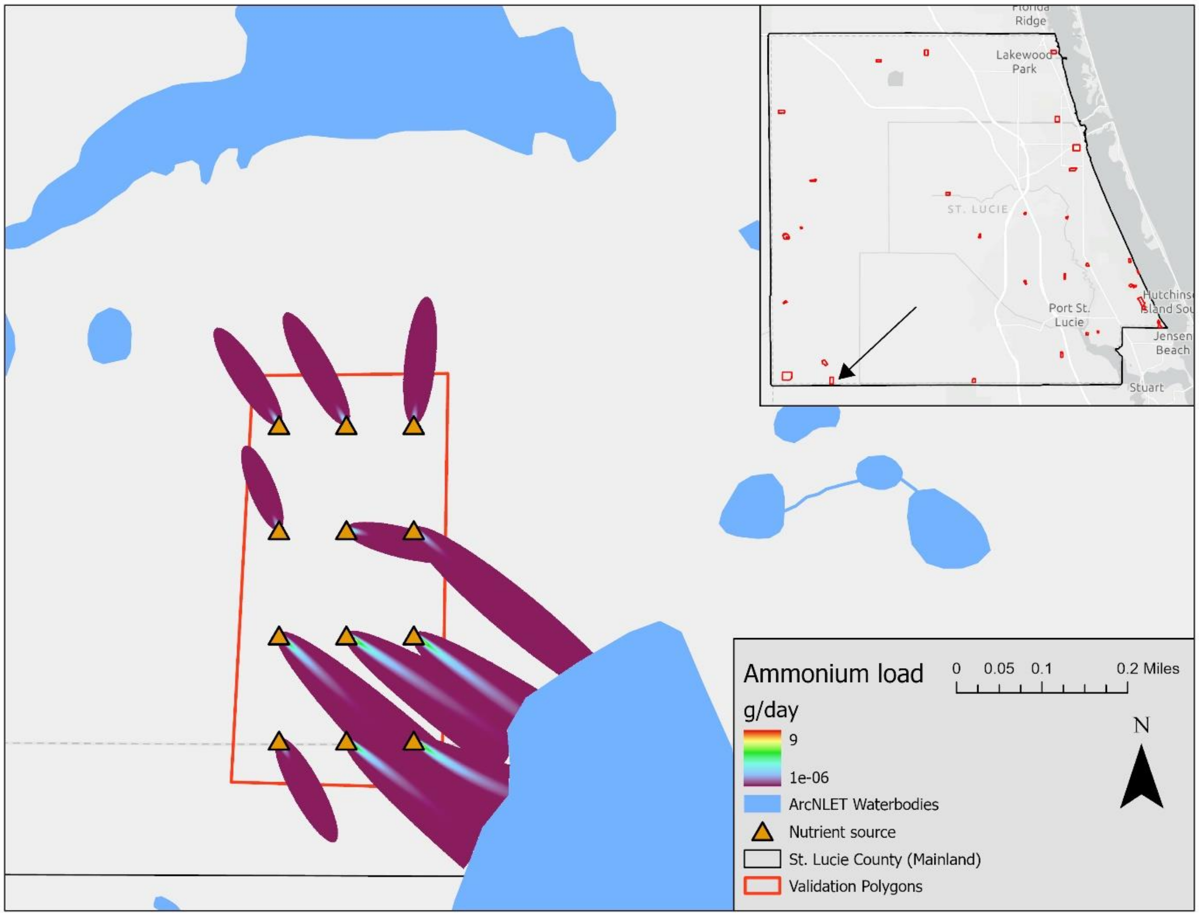


Figure C2. Example of ammonium plume behavior as modeled in a Task 3 Validation Polygon using ArcNLET. FSU researchers independently modeled the potential load of NO3, NH4, and total inorganic N to waterbodies at 120 point locations (12 per 10 polygons).

Subject Matter Expert Comparison

The risk categories assigned by four of the seven SMEs were consistent with the risk categories assigned by LARNLoad for over 90% of the 30 evaluation polygons. For the remaining three SMEs, their risk categorizations were consistent with those of LARNLoad for 87%, 60%, and 33% of the evaluation polygons (Table C3). Overall, there was an 80% agreement between the risk categories assigned by SMEs and those assigned by LARNLoad (Tables C3, C5). The average consistency **per polygon** between SMEs and LARNLoad risk categorization also was 80%.

Table C3. Comparison of the relative risk categories assigned by the LARNLoad model and by individual Subject Matter Experts (SME). SME names have been removed to preserve anonymity. Polygon numbers that appear in bold italics were randomly selected to be included in the ArcNLET comparison.

Polygon Unique ID	LARNLoad Rank	SME A	SME B	SME C	SME D	SME E	SME F	SME G
1	Lower	Lower	Higher	Lower	Higher	Lower	Higher	Lower
2	Lower	Higher	Lower	Lower	Lower	Lower	Lower	Lower
3	Lower	Lower	Higher	Lower	Higher	Lower	Lower	Lower
4	Lower	Lower	Higher	Lower	Lower	Lower	Lower	Lower
5	Lower	Lower	Higher	Lower	Higher	Lower	Lower	Lower
6	Lower	Lower	Lower	Lower	Lower	Lower	Lower	Lower
7	Higher	Higher	Lower	Higher	Lower	Higher	Higher	Higher
8	Higher	Higher	Higher	Higher	Lower	Higher	Higher	Higher
9	Higher	Higher	Lower	Higher	Lower	Higher	Higher	Higher
10	Higher	Higher	Higher	Higher	Lower	Higher	Higher	Higher
11	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
13	Higher	Lower	Higher	Lower	Higher	Higher	Lower	Higher
14	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Lower
15	Higher	Higher	Lower	Higher	Lower	Higher	Higher	Higher
16	Lower	Lower	Lower	Lower	Higher	Lower	Lower	Lower
17	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
18	Lower	Lower	Lower	Lower	Lower	Lower	Lower	Lower
19	Lower	Lower	Higher	Lower	Higher	Lower	Lower	Lower
21	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
22	Lower	Lower	Higher	Lower	Higher	Lower	Lower	Lower
23	Higher	Higher	Lower	Higher	Higher	Higher	Higher	Higher
24	Higher	Higher	Higher	Higher	Lower	Higher	Higher	Higher
25	Higher	Lower	Higher	Higher	Lower	Higher	Higher	Higher
26	Lower	Lower	Lower	Lower	Higher	Lower	Lower	Lower
27	Higher	Higher	Higher	Higher	Lower	Higher	Higher	Higher
29	Higher	Higher	Lower	Higher	Lower	Higher	Higher	Higher
30	Higher	Higher	Lower	Higher	Lower	Lower	Higher	Higher
34	Lower	Lower	Lower	Lower	Higher	Lower	Lower	Lower
35	Lower	Lower	Lower	Lower	Higher	Lower	Lower	Lower
36	Lower	Lower	Lower	Lower	Higher	Lower	Lower	Lower
Consistency between SME and LARNLoad categorizations (%), (average, 80%)		87	60	93	33	93	93	100

Confusion Matrices

Both the ArcNLET and the SME comparison methods demonstrated an 80% consistency with LARNLoad risk categorization (Tables C2 - C5).

Table C4. ArcNLET Comparison Results, Confusion Matrix

	LARNLoad Higher	**LARNLoad Lower**	**Total**
ArcNLET Higher	4	1	5
ArcNLET Lower	1	4	5
Total	5	5	10

Table C5. Subject Matter Expert Comparison Results, Confusion Matrix

	LARNLoad Higher	**LARNLoad Lower**	**Total**
SMEs Higher	84	21	105
SMEs Lower	21	84	105
Total	105	105	210

Discussion

The results indicate that LARNLoad exhibits consistent performance when compared against either a numerical model (ArcNLET) or the best professional judgment provided by project SMEs. LARNLoad relative risk categories are in 80% agreement with those assigned by either of these assessment methods, underscoring its reliability and alignment with both quantitative modeling and stakeholder judgement.

Neither LARNLoad, ArcNLET, nor SME opinion risk categories were based on field data collection. Therefore, the high degree of concurrence does not imply that LARNLoad is 80% correct, only that it is 80% consistent with other methods by which the likelihood of nutrient loading to waterbodies from OSTDS is commonly assessed in Florida. This high degree of concurrence indicates that LARNLoad can be used independently to assess risk or in concert with other methods with minimal risk of obtaining contradictory results. For example, LARNLoad provides an assessment of risk based on physical landscape properties that can be used efficiently to screen landscapes for effluent risk to waterbodies. If an area requires detailed numerical analysis, ArcNLET additionally may be used to develop insight at individual point locations or aggregated point locations.

There is no apparent pattern to the relatively uncommon disagreements between LARNLoad and ArcNLET. Each disagreement appears to be case specific. LARNLoad and ArcNLET are both models based on physical attributes of the landscape. However, the specific datasets, analysis resolution, and underlying calculations vary between models, which lead to slight differences in model outputs. This did not matter in the eight more obvious cases, i.e., where nutrient loading was clearly likely or clearly unlikely. This only mattered in the two more marginal cases, i.e., where nutrient loading was marginally likely or marginally unlikely. There were two evaluation polygons for which the risk categories assigned by LARNLoad and by subcontractors based on ArcNLET results differed. For these two polygons, #3 and #29, the risk categories assigned by 71% and 29% of the SMEs were consistent with the risk categories assigned by LARNLoad and ArcNLET, respectively.

There also is no apparent pattern to the relatively uncommon disagreements between LARNLoad and SME opinion. Again, each disagreement appears to be case specific. In this exercise, however, there are two definitions to "case": there are both comparisons between individual polygons (e.g., the risk categories LARNLoad and a SME assign to a particular polygon) and between individual SMEs (e.g., the risk categories SMEs A-G assign to a particular polygon). In the former case, one might again expect this to matter most in the more marginal cases, i.e., where nutrient loading was marginally likely or marginally unlikely. In the latter case, one might expect there to also be differences due to the personal biases of the SMEs (e.g., which specific factors they emphasize when assessing the likelihood of nutrient loading from OSTDS to waterbodies). In the latter case, however, one might also expect there to be differences due to the ways the SMEs understood the instructions and/or completed the exercise (e.g., misunderstandings of the evaluation instructions or technical difficulties with the online map or survey). This could explain why SME D results are significantly different from those of all other SMEs. If the model is expanded to other areas, it would be advisable to follow up with SMEs to gain insights into their decision-making processes, especially in cases where most other SMEs have similar responses.

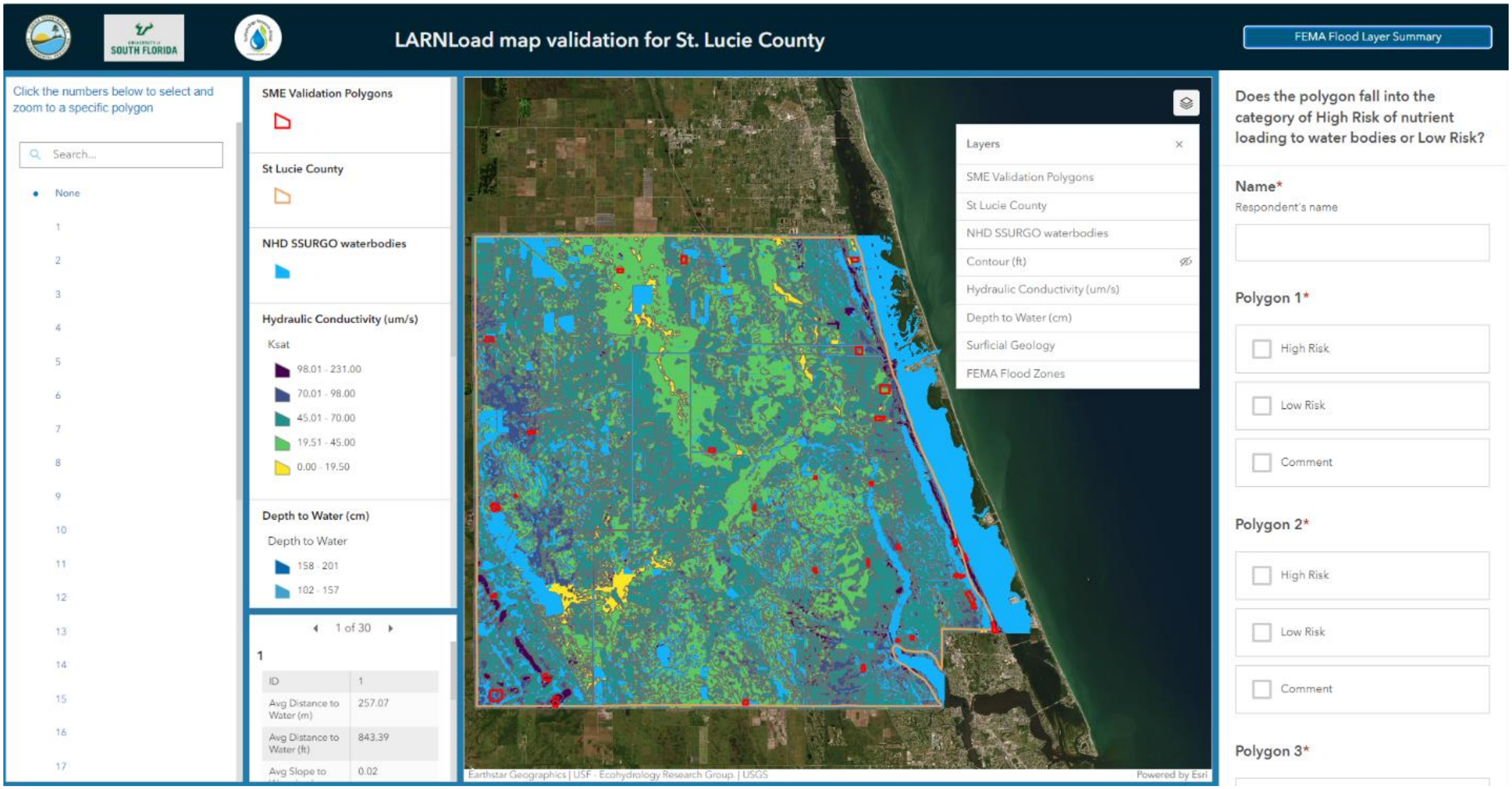
References

Mao, W., Core, M., & Ye, M. (2024). ArcNLET-Py: An ArcGIS-based nitrogen load estimation toolbox developed using python for ArcGIS pro. *SoftwareX*, *27*, 101816. https://doi.org/10.1016/j.softx.2024.101816

Rios, J. F., Ye, M., Wang, L., Lee, P. Z., Davis, H., & Hicks, R. (2013). ArcNLET: A GIS-based software to simulate groundwater nitrate load from septic systems to surface water bodies. *Computers & Geosciences*, *52*, 108–116. https://doi.org/10.1016/j.cageo.2012.10.003

Appendix D. Images of the Interactive Map Used by Subject Matter Experts During the Evaluation of LARNLoad

a.


LARNLoad map validation for St. Lucie County
FEMA Flood Layer Summary
Click the numbers below to select and zoom to a specific polygon
Search...
None
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
SME Validation Polygons
St Lucie County
NHD SSURGO waterbodies
Hydraulic Conductivity (um/s)
Ksat
98.01 - 231.00
70.01 - 98.00
45.01 - 70.00
19.51 - 45.00
0.00 - 19.50
Depth to Water (cm)
Depth to Water
158 - 201
102 - 157
1 of 30
1
ID
1
Avg Distance to Water (m)
257.07
Avg Distance to Water (ft)
843.39
Avg Slope to
0.02
Layers
SME Validation Polygons
St Lucie County
NHD SSURGO waterbodies
Contour (ft)
Hydraulic Conductivity (um/s)
Depth to Water (cm)
Surficial Geology
FEMA Flood Zones
Earthstar Geographics | USF - Ecohydrology Research Group | USGS
Powered by Esri
Does the polygon fall into the category of High Risk of nutrient loading to water bodies or Low Risk?
Name*
Respondent's name
Polygon 1*
High Risk
Low Risk
Comment
Polygon 2*
High Risk
Low Risk
Comment
Polygon 3*

b.

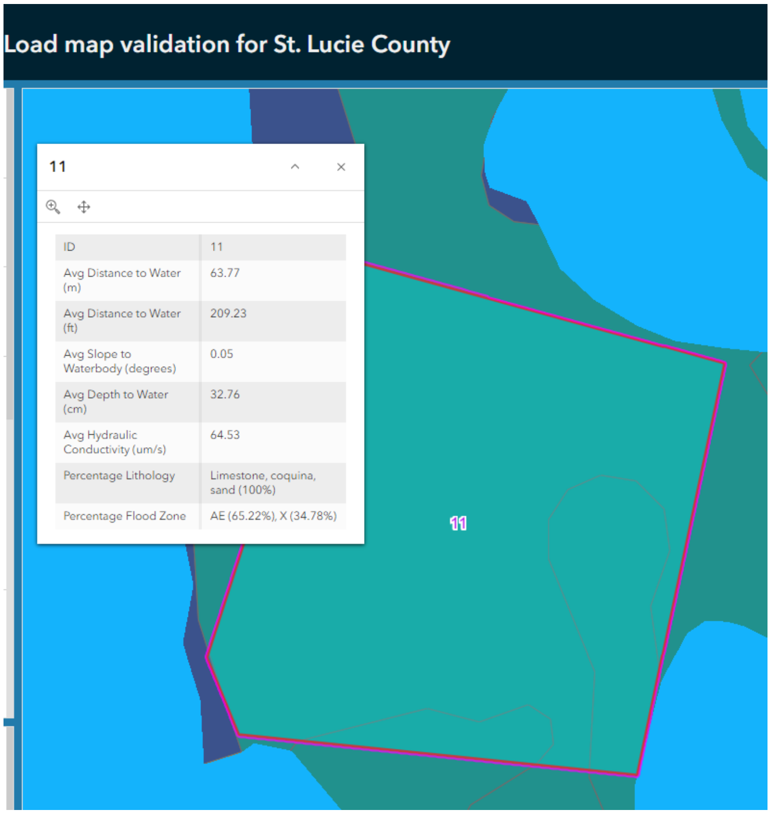


Figure D1. Screenshots from the interactive map used by subject matter experts (SMEs) to validate LARNLoad. (a, previous page) In the middle of the image is the study area. The red polygons represent the validation polygons used by SMEs for the analysis. On the right of the image are the response text boxes. To the left of the image are buttons to select to zoom in to each one of the validation polygons. (b, this page) Zoomed in image of validation polygon 11 with a summary of the physical landscape parameters pop up box.

Appendix E. LARNLoad Evaluation Instructions Provided to Subject Matter Experts

Landscape Vulnerability – Subject Matter Expert Validation, 6/24/2024, AT020

Background and Task Overview:
You participated in a virtual workshop June 2023 to rank the relative importance of six landscape attributes to potential nutrient loading to waterbodies in St. Lucie County. The exercise was conducted using Analytical Hierarchy Process and resulted in a model with exceptionally good internal consistency. The model is called Landscape Assessment of Risk for Nutrient Loading to Waterbodies, or LARNLoad. We subsequently used LARNLoad to produce a map of the relative risk of landscape positions to nutrient loading to waterbodies in St. Lucie County. LARNLoad is in the final evaluation stage.

We are employing two approaches to evaluate LARNLoad. In both, we are utilizing polygons selected from the LARNLoad map using a stratified random sampling design. In the first approach, we are comparing the relative risk categories obtained from LARNLoad to model nutrient loading obtained from ArcNLET. We hypothesize that modeled nutrient loading obtained from ArcNLET will be higher in the polygons that LARNLoad categorizes as higher risk and lower in the polygons that LARNLoad categorizes as lower risk. In this second approach, we are comparing the relative risk categories obtained from LARNLoad to relative risk categories obtained from you and the other SMEs. We hypothesize that there will be a high degree of congruity between these two sets of risk categories. To do this, we are asking you to assess the relative risk of nutrient loading to waterbodies at 30 polygons using a relative scale, i.e., “higher” vs “lower” risk. Once complete, we will evaluate the consistency of LARNLoad rankings with SME rankings by comparing the mapped LARNLoad ranks with those you enter.

Your assessment will be done “blind’, i.e., you will not have access to the LARNLoad map. However, you will have access to an interactive map containing the underlying landscape data layers and the polygon locations. Additionally, you will have access to a summary of the polygon landscape attributes in two formats, i.e., as polygon pop ups within the map and as a separate Excel product.

Important:
• **Base your risk assessment strictly on physical properties of the landscape, i.e., do not consider the current presence/absence of potential nutrient sources.** The LARNLoad risk assessment is based strictly on physical factors that related to the likelihood nutrients in that landscape position might make it to a nearby waterbody. Do not consider the current land use-land cover, the density of the development, the likelihood that there are OSTDS, the likely age of the OSTDS, or any other development-related factor.
• **Use a “relative” scale to rank each of the polygons**. Assign 15 of the polygons to higher risk and 15 to lower risk.

Procedure:
1. Review the **interactive map** containing the geospatial datasets listed below, each of which can be turned on or off. To zoom to a polygon, select the polygon number on the left panel.

List of Geospatial datasets:

- Study area boundary (mainland St. Lucie County)
- Polygons "SME Validation Polygons"
- Waterbodies
- Depth to Water
- Hydraulic Conductivity
- FEMA Flood Zones
- Topography (from which "slope" is derived)
- *Surficial Geology, Lithology – including presence/absence of shallow limestone

2. Review the landscape properties of each of the 30 polygons. These properties can be accessed via pop-ups within the map or via Excel format. To access the pop-ups, select the polygon outline on the map. The information provided in the Excel sheet is the same information provided in the pop-ups. Note, for a definition of FEMA flood zones, select the blue box in the upper right-hand corner of the map called: "FEMA Flood Layer Summary". For additional information regarding the "Surficial Geology" dataset, see the bottom of this document.

List of landscape properties summarized per polygon as pop-ups and in Excel format

- Average distance to a waterbody (meters and feet)
- Average depth to water (cm)
- Average hydraulic conductivity (um/s)
- Flood rating (FEMA) by polygon area (%)
- Average slope to a waterbody (degrees)
- *Surficial geology by polygon area (%) *

3. Sort the polygons into two categories:

- Determine which 15 polygons belong in a "higher risk" group and which 15 belong in a "lower risk" group. Do not consider the current presence or absence of OSTDS or other existing infrastructure, as these factors will be addressed at a later stage of the project.
- Note that the terms "high" vs "low" in this context are relative to this group of SME Validation Polygons. In other words, if the same amount of nutrient addition via OSTDS occurred at these 30 locations, which 15 locations would pose the higher risk to waterbodies and which 15 the lower risk to waterbodies?

4. Record your classification:

- In the panel to the right, for each polygon, select "High" or "Low." We have provided a comment box for you to record comments related to your selection. For example, if your assessment of "risk" is based on a waterbody depicted in the photo imagery that is not included in the Waterbody dataset, this should be noted in the comment textbox.

- Once you complete your assessment for all 30 polygons, review your final responses. An additional comment box is provided at the bottom of the menu for comments regarding the overall exercise. To finalize your selections, click the submit button.

Please reach out to us with any questions. Your participation is greatly appreciated!

Edgar Guerron-Orejuela
PhD student
edgarguerron@usf.edu

Kai Rains
Research Associate Professor
krains@usf.edu

'*Text from The Surficial Geology of Florida (aka "lithology") metadata: *"… If the shallowest occurrence of the karstic limestone is 20 feet (6.1 meters) or less below land surface, the limestone formation was mapped. If the limestone is more than 20 feet (6.1 meters) below land surface, an undifferentiated siliciclastic unit was mapped."*

Appendix F. LARNLoad Geodatabase Metadata

Detailed Description of Geospatial Components of LARNLoad.

Geospatial analyses were performed using ESRI ArcGIS Pro 3.1.0.

1. *LARNLoad map*
   LARNLoad was developed in ArcGIS Pro 3.1.0 by performing a weighted overlay analysis of six physical landscape parameters selected and ranked by importance by subject matter experts (SMEs) using Analytical Hierarchy Process (AHP) (FDEP Agreement AT015) (Figure F1). USF-ERG synthesized AHP data into a model to generate the LARNLoad parameter weights: *Distance to Waterbody,* 30%; *Depth to Water,* 21.6%; *Hydraulic Conductivity,* 20.7%; *Potential for Flooding,* 10.9%; *Slope,* 9.8%; and *Depth to Limestone*, 7.0%. In LARNLoad, landscape positions are classified according to the potential risk of nutrient loading to waterbodies. The LARNLoad risk ratings reflect the relative risk posed by the *physical properties* inherent to the landscape. The risk ratings do not reflect related factors that would require more frequent updating such as land use or the current presence/absence of nutrient loading factors. LARNLoad is designed to be used alone or in concert with other project specific information to facilitate decision-making.

   LARNLoad was evaluated by two independent assessment methods. A comparison between the risk ratings assigned by LARNLoad and those assigned in a blind study by subject matter experts returned a consistency rating of 80%. A comparison between risk ratings assigned by LARNLoad and nutrient loading model (ArcNLET) also returned a consistency rating of 80%.

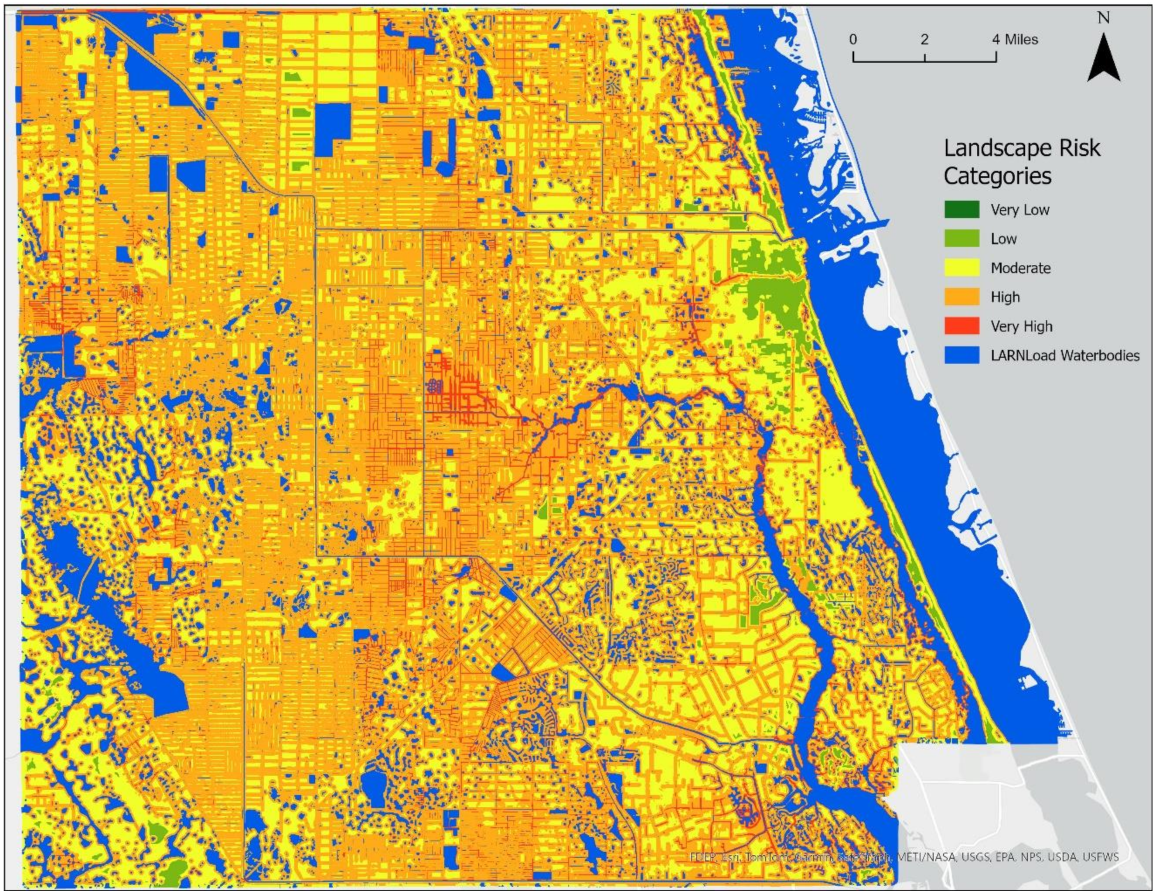


Figure F1. Landscape Assessment of Risk to Nutrient Loading to Waterbodies (LARNLoad) model developed in St. Lucie County.

2. *LARNLoad Waterbodies*

   LARNLoad Waterbodies contains features from *NHDPlus HR* (waterbody polygons, flowlines polylines (buffered by 2.5 ft), and area polygons) and the Soil Survey Geographic Database (SSURGO) ("water" and "ocean" polygons). These features were merged into a single comprehensive dataset *LARNLoad waterbodies* (Figure F2).

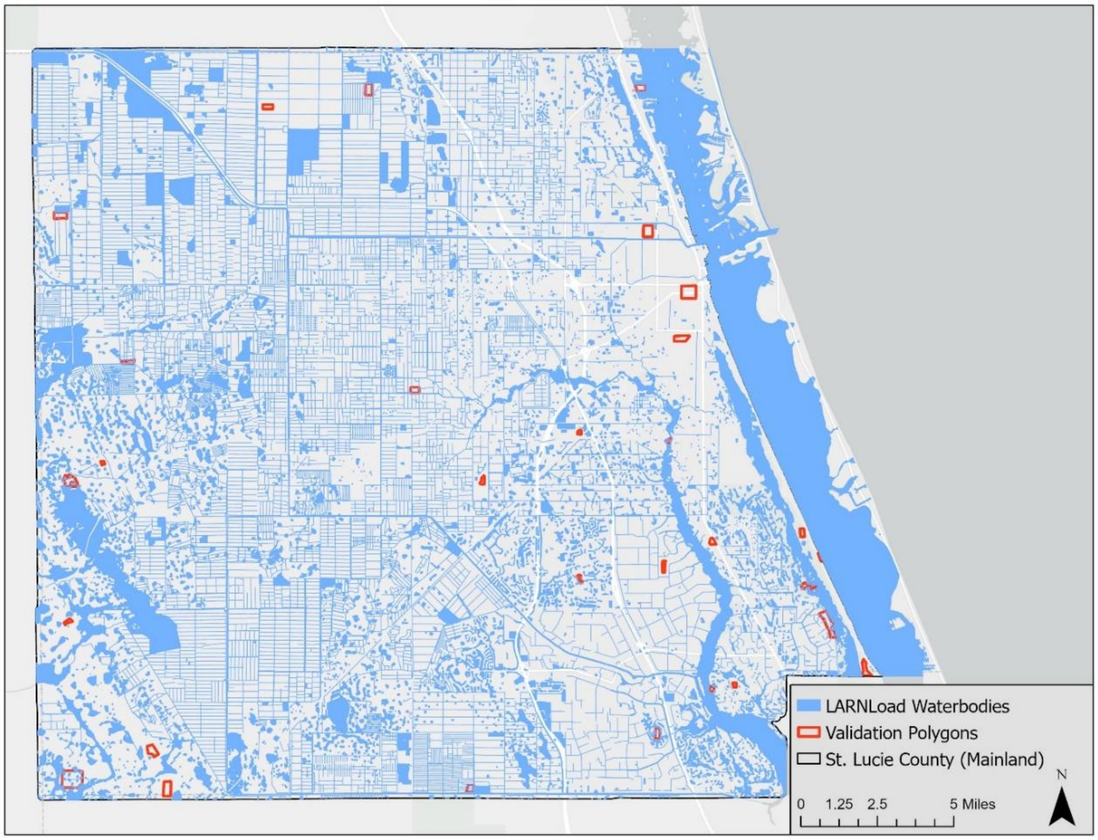


Figure F2. The waterbodies and locations of the polygons used to validate the final LARNLoad map are depicted in this figure.

3. *Distance to Waterbody*

Distance to Waterbody reflects the distance from any point (2.5 ft x 2.5ft) in the study area to features contained in the *LARNLoad Waterbodies*. Distance values were calculated using the nearest accumulated distance (Euclidean distance tool, ArcPro) to a LARNLoad waterbody. This dataset was converted to a raster (2.5ft). The range of raw values was 2.5ft – 3197.5ft. The raw values were classified into nine ranks: Rank 9, 2.5 – 45.99 ft; Rank 8, 45.99 – 93.6 ft; Rank 7, 93.6 – 140.42 ft; Rank 6, 140.42 – 187.2 ft: Rank 5, 187.2 – 233.99 ft: Rank 4, 233.99 – 280.81 ft: Rank 3, 280.81 – 327.99 ft: Rank 2, 327.99 – 656 ft: Rank 1, 656 – 3197.5 ft (Figure F3a).

4. *Depth to Water*
   The *Depth to Water* dataset is based on the weighted average depth to water attribute from the Soil Survey Geographic Database (SSURGO). Null values present in the SSURGO dataset were eliminated through the following procedure: 1) Delete SSURGO polygons that coincide spatially with *LARNLoad waterbodies* 2) Where null values persist, assign a value of 201 cm to all null polygons assigned in SSURGO to a soil type with a depth to water > 80 inches (200cm) or characteristic soil moisture regime of "Excessively Drained". Once completed, no null values remained, and the dataset was converted to a raster (2.5ft). The range in raw values was 0 – 201cm. The raw values were classified into nine ranks: Rank 9, 0 – 14.3cm; Rank 8, 14.3 – 28.6 cm; Rank 7, 28.6 – 42.9 cm; Rank 6, 42.9 – 57.2 cm; Rank 5, 57.2 – 71.5 cm; Rank 4, 71.5 – 85.8 cm; Rank 3, 85.8 – 100.1 cm; Rank 2, 100.1 – 200 cm; Rank 1, 201 cm (Figure F3b).

5. *Hydraulic Conductivity*
   The *Hydraulic Conductivity* dataset is based on the weighted average hydraulic conductivity attribute from the Soil Survey Geographic Database (SSURGO). The SSURGO dataset assigns null hydraulic conductivity values to several locations they map as "Pits" (i.e., "open excavations" as per USDA, 2017) in the study area. However, according to recent imagery, these pits have been filled since the soil survey was conducted. The composition of the fill deposit is unknown. As a regional representative of deposit characteristics, the hydraulic conductivity value present in the adjacent polygon with the longest shared border was assigned to null "Pit" polygons. Once completed, no null values remained, and the dataset was converted to a raster (2.5ft). The range in raw values was 10.35 um/s – 244.7 um/s. The raw values were classified into five ranks: Rank 9, >100 um/s; Rank 8, 75 – 100 um/s; Rank 7, 50 – 75 um/s; Rank 6, 25 – 50 um/s; Rank 5, 10– 25 um/s (Figure F3c).

6. *Potential for Flooding*
   This *Potential for Flooding* dataset is based on flood zone and flood zone subtypes originating from the FEMA *National Flood Hazard Layer* (NFHL): X (area of minimal flooding), X (0.2% annual chance flood), AE, A, AH, VE (1% annual chance flood), and AE (regulatory floodway). In the study area, the *NFHL* contains small slivers. To eliminate

slivers, they were assigned to the adjacent polygon with the longest shared border. This dataset was converted into a raster (2.5 ft) and the NFHL categories were classified into four ranks: Rank 9, FEMA flood zone AE (regulatory floodway); Rank 8, FEMA flood zones AE, A, AH, VE (1% annual chance flood); Rank 5, FEMA flood zone X (0.2% annual chance flood); and Rank 1, FEMA flood zone X (area of minimal flooding) (Figure F3d).

7. *Slope*
   The *Slope* dataset characterizes the change in elevation from any point in the study area to the average elevation of a natural waterbody (calculated per quarter-Township) divided by the distance from that point to the nearest waterbody (as per the *Distance to Waterbody* LARNLoad dataset). Natural waterbodies were distinguished from artificial waterbodies in *LARNLoad Waterbodies* by referencing attributes ("wetlands", "lakes", and "streams") assigned to spatially coincident water features in the *Land Cover Land Use* geospatial dataset (SFWMD, 2019). Raw elevation data were sourced from a recent digital elevation model (DEM, 2018-2020, 2.5 ft). The elevation change used in the calculation of "slope" was the difference between the DEM value at a point (2.5ft x 2.5 ft) and the average elevation summarized across all natural waterbodies within a particular quarter-Township (PLSS, BLM). Regionalizing waterbody elevations by quarter-Townships addresses concerns that regional trends in elevation will otherwise mask the small elevational differences between waterbodies and uplands. Distance data were obtained from the *Distance to Waterbody* LARNLoad dataset. The range in raw values was 0 – 1.55 degrees. The raw values were classified into nine ranks: Rank 9, 1.33 – 1.55 degrees; Rank 8, 1.14 – 1.33 degrees; Rank 7, 0.95 – 1.14 degrees; Rank 6, 0.76 – 0.95 degrees; Rank 5, 0.57 – 0.76 degrees; Rank 4, 0.38 – 0.57 degrees; Rank 3, 0.19 – 0.38 degrees; Rank 2, 0.1 – 0.19 degrees; Rank 1, 0 degrees (Figure F3e).

8. *Depth to Limestone*
   The use of the word "depth' in the name of this dataset implies continuous data. However, the underlying data obtained from the Surficial Geology of Florida (SGF) are categorical. In SGF, *"If the shallowest occurrence of the karstic limestone is 20 feet (6.1 meters) or less below land surface, the limestone formation was mapped. If the limestone is more than 20 feet (6.1 meters) below land surface, an undifferentiated siliciclastic unit was mapped."*

(Scott, 2001). Four SGF mapping units are present in the study area: 1) limestone, coquina, sand 2) sand 3) sand, clay, organics, and 4) shells, sand, clay. The SGF map was converted to a raster (2.5 ft) and the four categories were classified into two ranks: Rank 7, limestone, coquina, sand; Rank 3, “sand, clay, organics”, “sand”, and “shells, sand, clay” (Figure F3f).

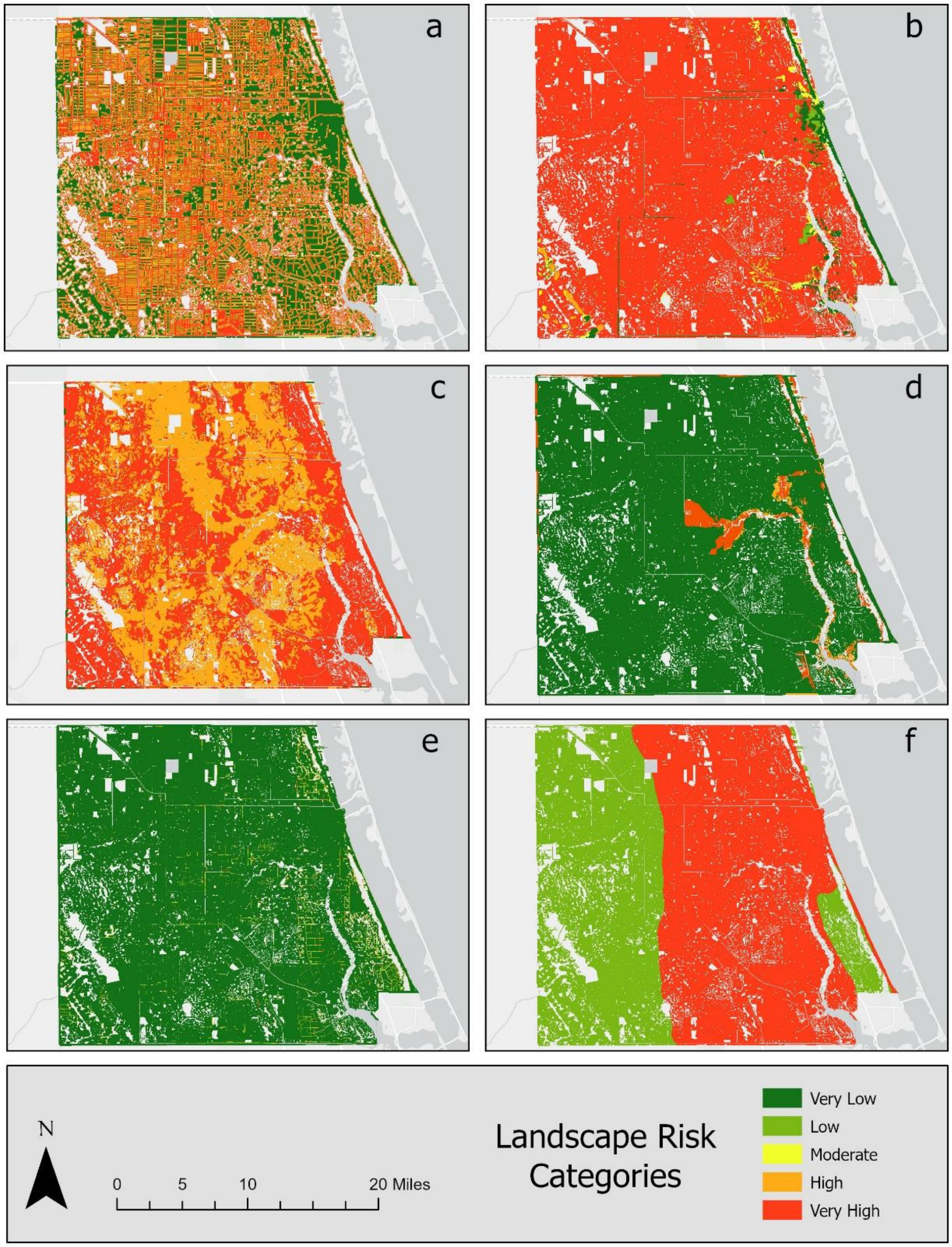


Figure F3. Distribution of landscape risk categories within geospatial datasets (a) *Distance to Waterbody*, (b) *Depth to Water*, (c) *Hydraulic Conductivity*, (d) *Potential for flooding*, (e) *Slope*, and (f) *Depth to Limestone*. The raw values of each dataset were standardized into ranks and then summarized into five landscape risk categories.

9. *Validation polygons*

The locations delineated by the 30 polygons in this dataset were used to evaluate “validate” *LARNLoad*. The locations were selected using stratified random sampling design. The study area was stratified by Township to ensure polygons were selected county-wide. *LARNLoad* was viewed at a scale of 1:5000 to identify contiguous sets of raster cells (minimum area was 7 square acres) classified as either very low/low risk “Low Risk” or very high/high risk “High Risk”. We delineated a minimum of one Low Risk and one High Risk polygon per Township except for nine Townships which lacked sufficient contiguous Low Risk raster cells. Fifteen Low Risk polygons and 15 High Risk polygons were randomly selected from the full set at random, based on Unique ID numbers, for inclusion in a validation exercise performed ‘blind’ by SMEs. Five Low Risk and 5 High Risk polygons were randomly selected for evaluation using ArcNLET. Per polygon, physical attributes were derived from the project geodatabase. The derived attributes are: Average Distance to Waterbody (m), Average Distance to Waterbody (ft), Average Slope (degrees), Average Depth to Groundwater (cm), Average Hydraulic Conductivity (um/s), Surficial Lithology (% of Polygon area), and Flood Zone (% of polygon area) (see Figure F2).