Development of Conservation and Restoration Targets for Sustainable Water Resource Management

Mike Britt, Natural Resources Division Director

WINTER HAVEN
The Chain of Lakes City

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Executive Summary

The Winter Haven City Commission approved the*Sustainable Water Resource Management Plan* in 2010,establishing a new direction for managing water resources in Winter Haven and the Peace Creek Watershed (Atkins 2010). The *Sustainability Plan outlines* an approach for managing watershed resources that relies on existing natural infrastructure, thereby reducing costs to the public and providing multiple benefits with respect to water quality, water supply, flood protection, and natural systems. The Sapphire Necklace was created as paradigm for sustainability in the watershed.

Impervious urban land uses and conversion of wetlands to developed land uses degrade watershed functions, which in turn contribute to flooding, soil erosion, water (and water supply) pollution, and loss of recreational uses of waters. Integrating ecosystem benefits (or services) into land use planning has only recently become part of a sustainable planning approach (Collins et al. 2007). This project, the *Development of Conservation and Restoration Targets for Sustainable Water Resource Management* (or *Resource Targets),* further develops the concepts presented in the *Sustainable Water Resource Management Plan* by developing and presenting a model of conservation and restoration target areas for the watershed.

The purpose of this project was to develop conservation and restoration targets that can be used to support future decisions related to land use in the City of Winter Haven and the Peace Creek watershed. To accomplish this, available data for surface water, groundwater, and habitat resources were screened for relevance and scale appropriateness and then ranked as a means of combining data with different units of measure. A Geographic Information System (GIS) platform was used to integrate the data and individual GIS layers were developed that represent five water resource functions: surface water quantity, surface water quality, groundwater quantity, groundwater quality, and habitat. Data intercepts representing the relationships, or links, between the resource functions (e.g. surface water quantity) and benefits (e.g. water supply) were used to develop the resource function layers. The five resource function layers were subsequently analyzed with respect to pre-developed (or un-impacted) conditions.   Target areas with the least (or no) difference with respect to undeveloped (e.g. circa 1940s) conditions are referred to here as *conservation* targets, and areas that exhibit the greatest change from historic conditions (or most impacted) are referred to as *restoration* targets.

Surface and ground water quantity data were the most comprehensive in terms of GIS data and provided an opportunity to focus on surface and ground water storage in the watershed. Merged, these two resource layers form a landscape-scale composite water resources data layer. The integration of additional project-specific and locally-specific data were used to refine those areas of the watershed for which these data were available. The product is a map of the water resource management “target areas” in the watershed. In addition to spatial extent of targets, this study documented an estimated loss of 20,815 acre-feet of surface water storage loss since the 1940s as a result of the loss of wetlands and reduced lake levels.

A GIS “button” tool was developed to automate scenarios for different combinations of resource functions. The tool allows the user to weight resource functions differently, thereby assigning relative importance to individual resource function layers, and create a resource target map. Evaluating impacts of proposed projects is the most straightforward use of the restoration targets. A scenario could be developed and evaluated based on relative importance of each resource function layer and the footprint of, for example, a proposed project, i.e. the user could quantify the total impact of a proposed project on one, five, or a combination of some of the five resource layers.

Conservation and resource targets also provide a mechanism for selecting locations for conceptual projects and feasibility studies, identifying opportunities for trade-offs between development and ecosystem benefits, quantifying a loss of services and mitigating for that loss. For example, opportunities to mitigate for impacts to groundwater elsewhere in the watershed can be readily identified. The resource targets provide a context for land use measures to guide revisions to land use ordinances and development

regulations and to develop incentives for protecting water resources.

Identification of areas for future restoration and conservation is even more important from a planning perspective. The resource targets developed for the Peace Creek watershed provide locations for restoration and conservation in the watershed, based on available watershed-level data. Once these targets become part of the planning process, specific restoration and conservation projects can be located appropriately throughout the watershed, while development can be directed in a way that is consistent with the restoration and conservation targets.

Local governments face challenges to using land use planning to protect water resources and associated community benefits. Therefore, to the extent that restoration and conservation of priority locations cannot be accomplished through land planning and other non-structural controls, engineering and other structural controls will need to be identified. These controls are less effective and more costly to implement than non-structural controls and, therefore, local governments should consider leveraging its land planning authorities, including using incentives to protect water resources, to the greatest extent possible. The City may also choose to implement monitoring and other feedback mechanisms for adaptive management of water resources. Identifying the resource targets allows the implementation of strategies to examine specific projects, options for land use planning, and private sector concepts such as mitigation banking and regional stormwater ponds. Some communities have established goals that target tree canopy increases in recognition of air and water benefits, while others have imposed regulatory jurisdiction over land use to prevent development because the costs associated with land use regulation and land acquisition were less than the costs of building additional water treatment facilities that would be necessary if the development was permitted.

The City of Winter Haven may, for example, choose to restore a portion of an estimated 20,815 acres of surface water storage lost to conversions to other land uses (primarily urban and agriculture). Or, stakeholders may choose to focus restoration efforts on only restorable (non-urban) areas, or any combination of these efforts. Estimates of loss of water storage were consistent with previous patterns identified for water quantity and reflect differences in ridge (Winter Haven Ridge) and valley (Polk Uplands) geology that dominate the watershed. Water storage restoration targets included predominantly the ridge lakes in the Southern Chain of Lakes, while lakes identified for conservation included mostly valley lakes in the Northern and Interior Chain of Lakes (consistent with results of the recently completed study of the Interior Chain of Lakes). Another practical option is restoration of storage that can be recovered without impacting adjacent land owners. In contrast, areas of water storage that remain unchanged (or with little change) are identified as conservation targets and include lakes Hamilton, Henry, Haines, Rochelle, and Smart in the Northern Chain of Lakes.

The resource targets developed for this project provide a model for revising the City's ordinances and developing incentives to protect water resources in the watershed. These mechanisms will be developed as part of the next step in carrying out the *Sustainability Plan*. This report presents the resource targets that can be used to evaluate, direct, and support land use decisions that contribute to sustainability in the entire watershed, including the portion of the watershed that forms the Sapphire Necklace, which was the focus of the *Sustainability Plan*. The resource targets are presented as conservation and restoration maps that provide the watershed context in which to focus and develop a range of water management alternatives. These alternatives, as well as the rules, ordinances, and other planning mechanisms to implement them, will be accomplished as part of future planning and design charrettes with City staff.

1. Introduction

The Winter Haven City Commission approved the*Sustainable Water Resource Management Plan* (or "Plan") in 2010, establishing a new direction for managing water resources in Winter Haven and the Peace Creek Watershed (Atkins 2010). The Plan outlines an approach for managing water resources in the watershed (Figure 1) that relies on existing natural infrastructure that will reduce costs to the public and provide multiple benefits with respect to water quality, water supply, flood protection, and natural systems. For example, impervious urban land use and conversion of wetlands to developed land uses degrade watershed functions, which in turn contribute to flooding, soil erosion, water (and water supply) pollution, and loss of recreational uses of waters. A resource *function* is defined as an operation or purpose natural to the resource, such as water quantity and/or quality. Resource *benefits* are defined with respect to the human environment and include such things as flood control and recreation. Flood control is considered a benefit of resource functions such as water quantity and habitat rather than a function itself. Land use change is an important factor affecting flood vulnerability. Managing for the appropriate configuration of natural cover could save billions of dollars in damages (Costanza et al. 1997) but, since they are "free", there is no financial trigger for society to change in response to the loss of these processes (Chan et al. 2006). Recreation and cultural aesthetics, too, are water resource benefits rather than resource functions, and outdoor recreation opportunities correspond with natural and semi-natural landscapes.

The idea of restoring former wetlands to nature parks and water front areas for new development plays a key role in achieving sustainability, defined here as the balance of social, economic, and environmental needs for future generations (EPA 2012). Implementing the plan relies on the capacity of the landscape to provide the water resource benefits. The fundamental life support services that natural ecosystems perform, and on which human civilizations depend, was recognized by the scientific community in the 1990s (Daily et al. 1997). However, integrating ecosystem benefits (or services) into land use planning has only recently become part of a sustainable planning approach (Collins et al. 2007). Ecosystem benefits include the treatment (purification) of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and production and maintenance of biodiversity, which in turn support agricultural, pharmaceutical, and industrial enterprises.

The concept of ecosystem benefits is a primary component of this *Development of Conservation and Restoration Targets for Sustainable Water Resource Management (or Water Resource Targets)* project, which in support of the Sustainability Plan, establishes water resource targets so that as economic growth continues, resource benefits such as water supply and quality can be restored and/or conserved. The *Water Resource Targets* project further develops some of the concepts presented in the *Sustainable Water Resource Management Plan* by developing and presenting a model that represents the areas to be considered for restoration and conservation, and therefore as guidelines for directing future land use in the watershed to mitigate for historic losses of, for example, water storage. For this project, data relevant to each of the resource functions of interest were incorporated into a Geographic Information System (GIS), thereby providing a data-driven support tool for future decisions related to land use and restoration projects. Data were used to identify relationships between water resource functions, including habitat, groundwater quantity, groundwater quality, surface water quantity, and surface water quality, and corresponding community benefits, i.e. fish and wildlife habitat, drinking water supply, clean groundwater, surface water storage and flood protection, and swimmable/drinkable/fishable surface water, respectively. Comparisons between undeveloped and present conditions were made to identify conservation (little change from historic conditions) and restoration (greater change from historic conditions) targets. While beyond the scope of this project, future implementation strategies will examine specific projects, options for land use planning, and private sector concepts such as mitigation banking and regional stormwater ponds.

This report presents methods, results, and conclusions with respect to the *Development of Conservation and Restoration Targets for Sustainable Water Resource Management* project. The tasks listed below are those outlined in the scope of work (SOW) approved by the Winter Haven City Commission earlier this year and completed for this project. Each task is addressed in subsequent sections.

Task 1:Compile and evaluate data. Numerous data sources were compiled and reviewed for appropriateness to the project.

Task 2: Develop water resources functions and benefits relationships. Data were selected for value in characterizing the water resource functions and benefits, and therefore the restoration and conservation areas.

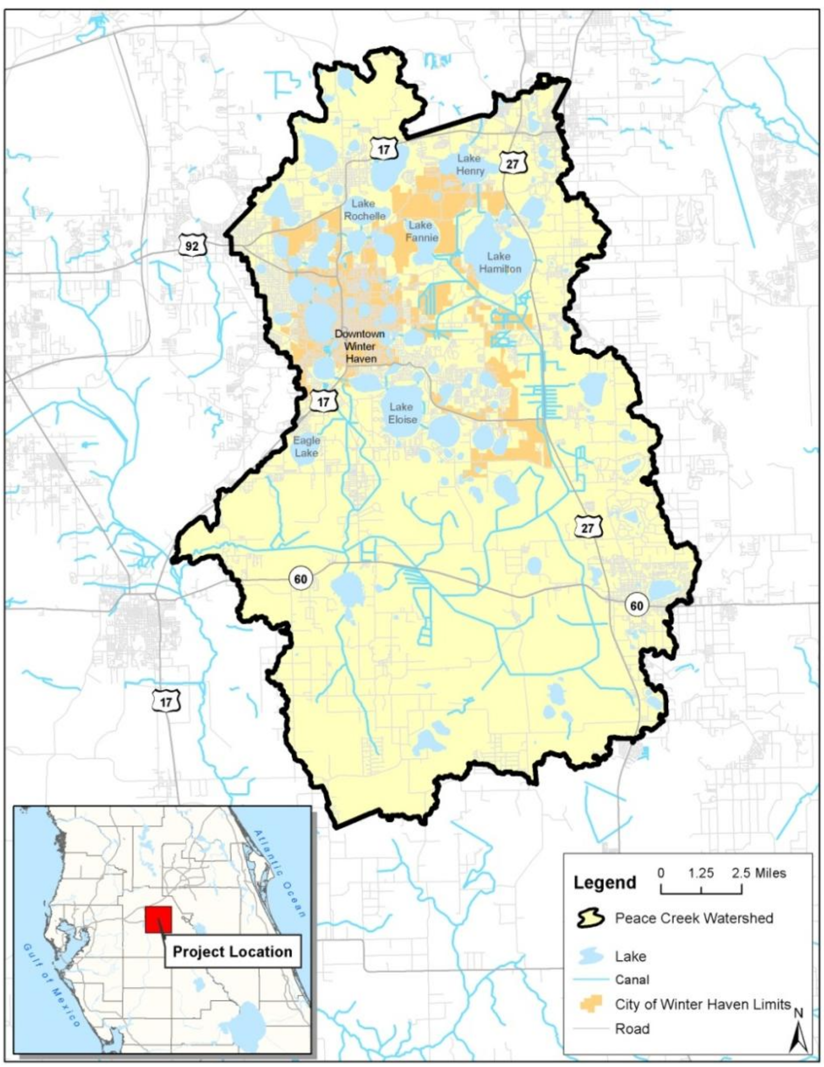
Task 3: Integrate data matrices into a GIS. Data were entered into a GIS for analysis and display.

Task 4: Quantify data-matrix-landscape intercepts. This task is designed to assign values to the different functions that landscapes can provide for water resources. Some land is ideal for recharge, other for storage, treatment or flood control. Each area of the watershed was evaluated based on its role in enhancing water resources. Data were evaluated and ranked as a means of merging multiple data sets into a composite data layer for each resource function.

Task 5: Develop and display conservation and restoration targets. Resource function layers were ultimately ranked and merged into a single, representative restoration and conservation layer. In addition to the approved SOW, a GIS tool was developed to automate analyses of impacts to resources under various future development scenarios.

Task 6: Prepare final deliverables, including maps and report. A report, maps of each resource function layer and resource target layer, GIS files, and GIS tools were completed and submitted to the City of Winter Haven.

Figure 1. Peace Creek Watershed, the City of Winter Haven, and the Winter Haven Chain of Lakes.



2. Methods

Five water resource functions were defined to characterize the hydrologic and ecological character of the Peace Creek watershed: groundwater quantity, groundwater quality, surface water quantity, surface water quality, and habitat. These functions were developed to complete Tasks 1 through 4 and are addressed individually for each of the five resource functions. Conservation and restoration targets were developed under Task 5.The resource benefits matrix presented in Table 1 summarizes the links between the resource functions (GIS layers) and benefits to the community. For example, groundwater recharge is a water resource function and a measureable attribute (i.e. recharge potential) that translates to resource benefits including water supply, water quality, fish and wildlife habitat, etc. These relationships are presented in the following sections and greater detail on these relationships was presented in previous documents, including the *Peace Creek Watershed Sustainability Plan*. The approach to building and integrating the GIS layers relied on the following primary components (outlined below).

- Conservation and restoration targets were developed at a scale consistent with that of available, relevant data. For example, land cover data are available for the entire watershed and illustrate differences between the more developed northern and less developed southern watershed.

- Data were acquired and “hard wired” for the analyses, while in later steps, data were ranked as a means of evaluating the landscape, both temporally (historic vs. existing) and spatially (across the watershed). This precludes the use of data that are not available for the entire watershed.

- Third, the data were ranked as a means of scoring data that have different units of measure.

- A GIS “button” was developed that allowed the user to evaluate changes in resource functions in various combinations (e.g. with and without habitat data).

- Data were integrated to provide composite water resource data layers.

- Locally-specific data were added to the watershed-scale data to refine areas for which more specific data were available and presented as the water resource management target areas.

Ninety-six available data sources were reviewed to identify data necessary to identify functional relationships between the resource functions and benefits (Tasks 1 and 2).Data sources and detailed source citations are listed in Appendix A. Those data that were available, but insufficient in areal extent to cover the watershed, characterized by limited or no relationship to evaluating the resource benefit (e.g. aquifer transmissivity), or precluded quantification of targets, were subsequently excluded from further analyses. Fifteen individual data layers were selected for use in the analyses of resource targets based on the availability and relevance of the data to each resource function (e.g. habitat, groundwater quantity data layers). A map of each data layer is provided in Appendix B and they were integrated into the GIS and combined with other layers to characterize the resource function layers (Task 3).

Since each data source represents data with different values and units of measure, data were assigned ranks with regard to the data layer being evaluated. In the same way that non-parametric statistics rely on ranked data when conventional parametric analyses are inappropriate, data were ranked for the present analyses as a means of allowing comparisons across resources (Task 4). Altered conditions were assigned a value = ”-5” (representing restoration), while relatively pristine conditions were assigned a value = “+5” (representing conservation) with respect to a particular resource function (e.g. surface water storage).Values of “0” were assigned to data if a restoration or conservation condition could not be established (i.e. insufficient data). Therefore, areas in which the potentiometric surface has declined were ranked “-5” while areas where it has not declined were ranked “+5.”

Table 1. Resource benefit function matrix: Indicates relationships between resource functions and benefits (x indicates relationship).

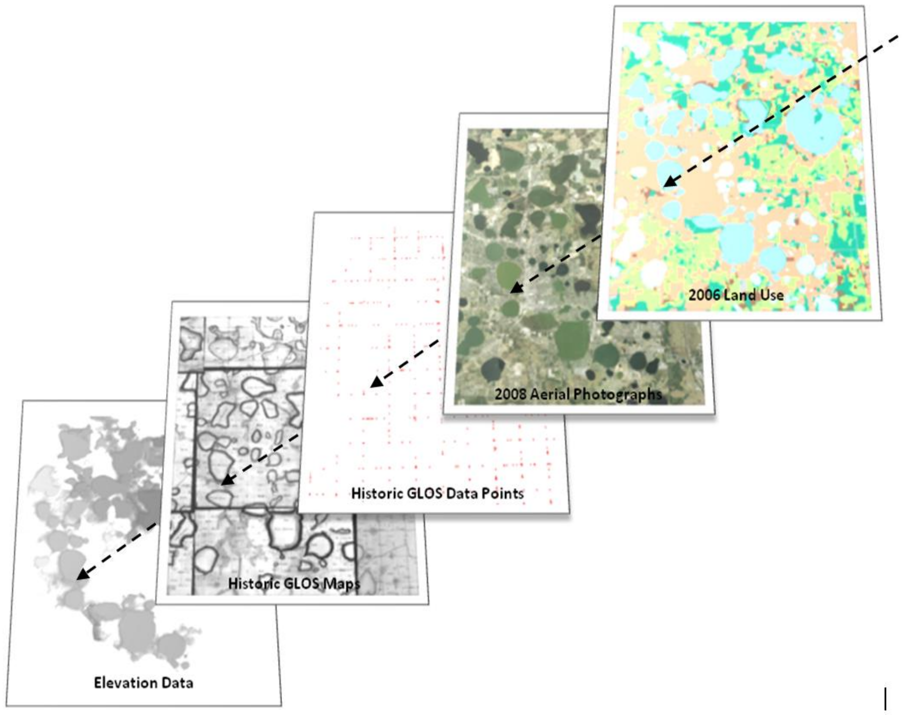
Water Resource Functions	Data Attribute	Water Resource Benefits (Targets)				
		Water Supply	Water Quality	Flood Protection	Fish and Wildlife	Recreation/ Cultural Resources
Groundwater				-		
Storage	Potentiometric surface	x	x	x		
Discharge (to surface water)	NA	x	x		x	x
Recharge	Recharge	x	x	x	x	
Hydraulic conductivity	Soils	x	x	x		
Quality	RCRA, SWAA					
Surface Water						
Nutrient transport/mediation	Impairment		x		x	
Sediment stabilization	NA		x		x	x
Storage	Water levels	x	x	x	x	x
Discharge (to surface and groundwater)	Recharge*	x	x	x	x	x
Water transport	Connectivity*	x		x	x	x
Quality	Impairment					
Habitat						
Climate regulation	NA	x				x
Nutrient assimilation	NA		x		x	x
Groundwater mediation	Groundwater*	x		x	x	x
Surface water mediation	Surface water*			x	x	x
Soil formation	Soils*	x	x	x	x	
Connectivity	SHCA	x	x	x	x	x
Effect on other resource functions**	FLUCFCS	x	x	x	x	x

*Data layers included under a previous resource function. **FLUCFCS used in combination with other resource function data layers as a measure of urbanization impacts. NA=not available.

Data were compiled for each resource function and ranked. Then, ranks were averaged between individual data layers for each resource function, thereby integrating individual GIS data layers to form a composite resource function (e.g. surface water quality) data layer for the watershed. The composite layer is the equivalent of the resource function layer (Figure 2). For example, the habitat function is a composite of listed species data, habitat type, land use, and adjacent land use, and also addresses connectivity among habitats that typically reflect streams and wetlands.

Scenarios were created for conservation and restoration targets map by integrating the five resource function layers. A location for which averaged ranks among the five resource function layers indicated relatively pristine water quality conditions, unaltered groundwater and surface water conditions, and "natural" fish and wildlife habitat also represented a location with a high conservation potential. In contrast, a location in which all these resources are altered would be assigned a high value for potential restoration. Average rankings may be modified for later efforts to address data layers in which some attributes may address specific functions. Final composite water resource data layers and the water resource management target areas were based on these scenarios.

Figure 2. Example of integration of data layers used to evaluate resources and develop resource conservation and restoration targets.



Tasks 1 through 4 included compiling and evaluating relevant data, establishing relationships between data and resources, integrating the data into the GIS, and quantifying the merged data across the watershed (landscape).A data summary is provided in Figure 3 and the more detailed data and ranking process is presented in Figure 4. Data were first accessed and examined for relevance to characterizing the particular resource function, such as surface water, groundwater, or habitat (surface and groundwater were further segregated into surface water quality and quantity and groundwater quality and quantity). Some data were then integrated or combined with a second data layer to produce the appropriate data field for analysis (e.g. land use was used in combination with recharge data to identify high vs. low recharge areas). Next, ranks were assigned to establish potential conservation ("+5") or restoration ("-5") to each location. Integrated (or composite) data layers were developed from the individual data layers by summing and averaging data for each location across the watershed. Weights were then assigned to each resource function layer to generate scenarios for potential water resource targets. In addition, impacts of development can be calculated for each scenario.

As part of these tasks, values were assigned to the resource functions that landscapes can provide with respect to water resources. Some land is ideal for groundwater recharge, other land is better suited for surface water storage, treatment, or flood control. Undeveloped high and moderate infiltration soils were identified for conservation, developed high and moderate infiltration soils were identified for restoration, and slow and very slow infiltration soils were not identified for conservation or restoration. Because of the landscape level at which this project was developed, the proposed Central Polk Parkway footprint is displayed in maps throughout the document as both a means of reference and context.

While field verification was not part of this project, knowledge of local site conditions from Atkins scientists and engineers, available reports, and local input provided watershed-level verification. As described earlier, if current and historic land cover are classified as wetland, that area was designated as conservation.

Conversely, if it was historically an open water wetland and is now uplands (or a “drier” wetland such as forested wetland) it is designated restoration. There were instances in which current land cover data identified an area as a wetland when it is actually in agriculture, albeit wet. These areas were designated as conservation instead of restoration. For example, in the case of the Mann-owned property at C.R. 540 and U.S. 27, the wet agriculture field is classified as herbaceous wetland (possibly not field verified). In the case of Lake Lulu, the forested wetland is still intact and the aerial photography interpretation cannot discern between wet and dry wetland forest.

To address some of these issues, water storage data from the Peace Creek watershed study were used to further refine the analysis. The surface water restoration and conservation targets were combined with the storage areas to identify areas that may have been designated as conservation when they should be restoration. A composite of data layers was mapped that displays data that are available, and ranked, at the watershed scale. A second map, or model, was developed that further refines areas for which additional data are available and displays the water resource management targets in the watershed. The City’s Sapphire Necklace, lakes with designated minimum levels, and stressed lakes were also added to provide context for the resource target areas. While the composite map is purely watershed-level data driven, the Water Resource Targets map includes additional planning information.

Figure 3. General approach to developing conceptual conservation and restoration resource targets.

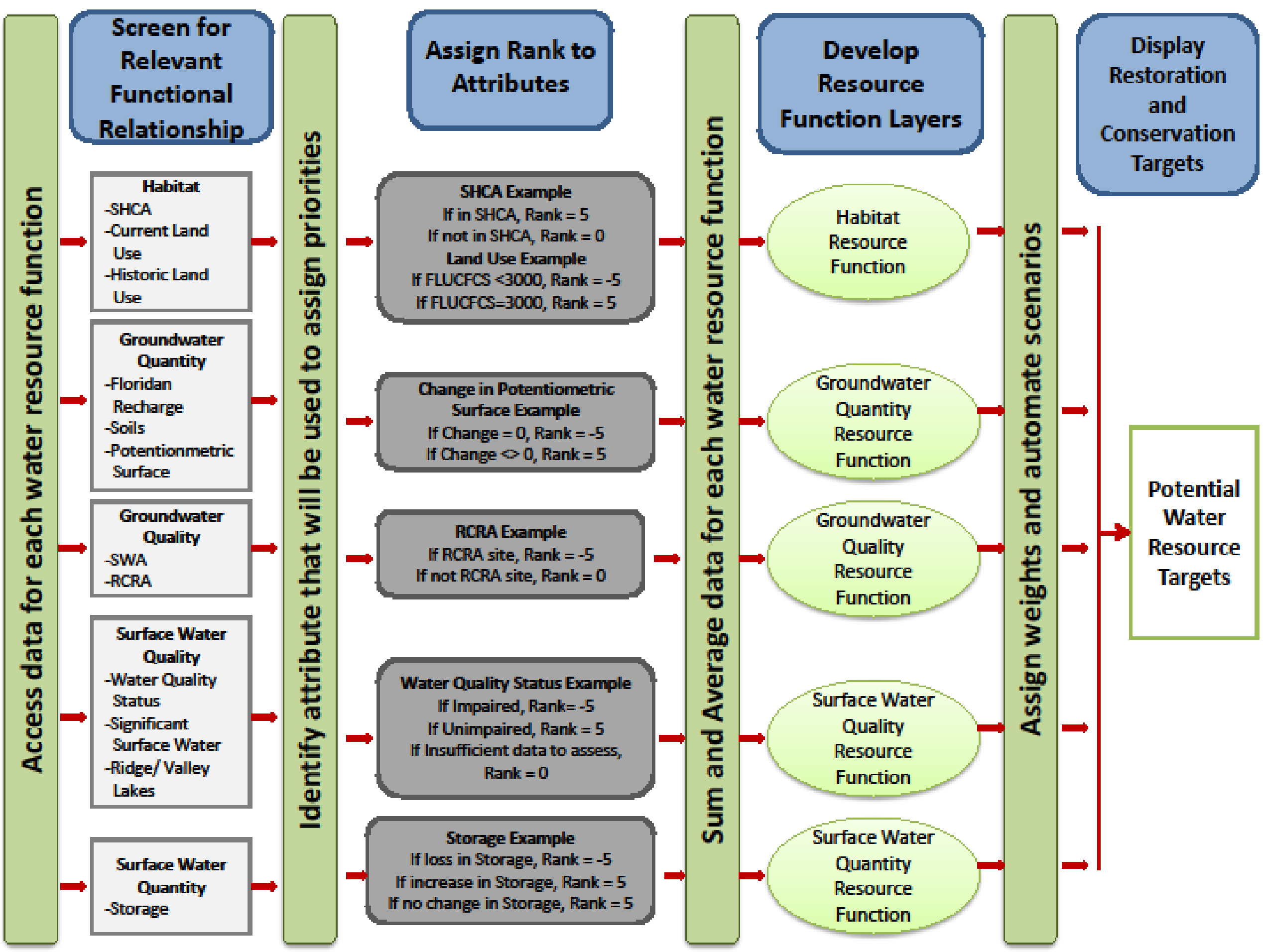


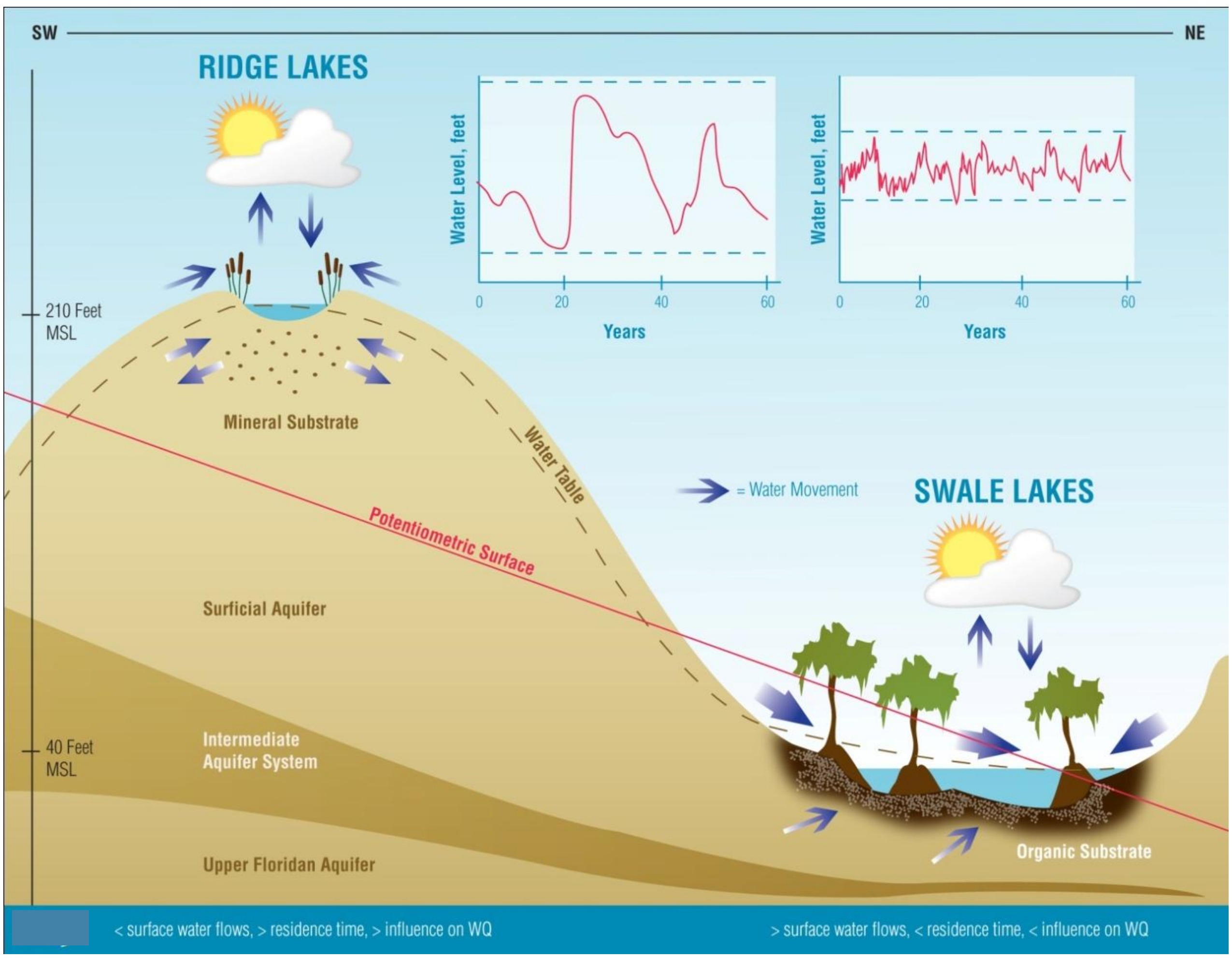
Figure 4. Data layer compilation, ranking, and mapping for conservation and restoration targets development (left to right).

1. PROMPT: Choose data layers for each water resource function	Data Layers	Resource Function	2. PROMPT: Choose data layer to combine	Data Additions/Combinations			3. PROMPT: Choose data field to be used for ranking for each data set	Data Fields	4. PROMPT: Rank parameters in chosen data field	Rank Value			5. PROMPT: Weigh resource function layer	Product: Conservation/ RestorationTarget Scenario
				2009 Land Use	2008 Potentiometric Surface	Watershed Delineation				-5	0	5		
	Floridan recharge	Groundwater Quantity		x				Recharge		Developed/ Recharge > 10	Undeveloped/ Recharge 1 to10	Undeveloped/ Recharge > 10		
	Pre-development potentiometric surface				x			Change		Change = 0	N/A	Change <> 0		
	Soils			x				Infiltration		Developed/ A, B	C, D, B/D	Undeveloped/ A, B		
	Source Water Assessment Areas (SWA)	Groundwater Quality						500-ft buffer		Inside 500-ft buffer	Outside 500-ft buffer	N/A		
	Resource Conservation and Recovery Act Facilities	Groundwater Quality						500-ft buffer		Inside 500-ft buffer	Outside 500-ft buffer	N/A		
	Historical land use	Surface Water Quantity		x				PRE_FLUCFCS		Loss of Storage		Gain /No Change in Storage		
	2009 Land Use							FLUCFCSCODE						
	Ridge/valley lakes	Surface Water Quality		x		x		Impacted		Developed/ Impacted	Insufficient data	Undeveloped/ Not Impacted		
	Significant surface water							Priority		N/A	0	Priority 1 - 7		
	Water quality status					x		Impaired		Impaired	Insufficient data	Not Impaired		
	Strategic Habitat Conservation Areas (SHCA)	Habitat						Priority		N/A	N/A	Priority 1 - 5		
	Historical land use							PRE_FLUCFCS		N/A	N/A	Cypress, Sand Pine		
	2009 land use							FLUCFCSCODE		Residential, Tree Crops	N/A	Cypress, Pine Flatwoods		

2.1. Groundwater Quantity

Groundwater typically provides base flow to rivers, streams, lakes, and wetlands, and declines in groundwater levels can reduce surface water levels in these surface water bodies, as well as springs and spring-fed rivers, and subsequently affect water supply, habitat, and recreation. For example, interactions between ground and surface water in the watershed (Figure 5) illustrate the greater influence of groundwater interactions on ridge lakes (when compared with swale or valley lakes), as well as the relative proximity of the potentiometric surface. These relationships were summarized in Table 1. Groundwater recharge is reduced when water that historically percolated through the soils into the groundwater is diverted across the land surface because the surface has been made impermeable (e.g., urbanized). Groundwater is recharged by primarily rainfall and subsequent soil percolation and discharges to lower gradient surface waters. Recharge also occurs via “leakance” from adjacent aquifers and discharges from surface waters into lower groundwater levels. An undisturbed groundwater supply is characterized by relatively independent and stable recharge (Ming et al. 2011) without which groundwater levels decline. Groundwater levels may be further impacted by water withdrawals for agricultural and potable use that can result in severe soil subsidence in wetlands and sinkhole formations in some areas. Potentiometric contours represent and account for variations in hydrogeologic conditions, such as water levels in wells, variable effects of pumping, and changing climatic influence (Ortiz 2009).Identifying potential areas of conservation provides an opportunity to prevent degradation of areas in which groundwater quantity can be characterized as relatively unimpacted and better manage these areas.

Figure 5. Diagram of relationships among rainfall, surface water, and groundwater in the Winter Haven Chain of Lakes.



Areas identified for restoration provide opportunities to develop projects to improve groundwater protection, improve conditions necessary for recharge, and evaluate the amount of recharge that may be recovered. The restoration and conservation targets will allow the use of more specific data, such as well field withdrawals or designated lake levels, to narrow the field of potential projects.

The groundwater quantity data layer developed for this effort represents the link between various physical properties of the groundwater resource functions and benefits. Links between groundwater functions (e.g., groundwater storage; discharge into wetlands, lakes, and streams; and recharge via rainfall percolation into the ground) and resource benefits such as water supply, water quality via percolation through the ground, flood protection via water storage and groundwater conveyance, habitat for fish and wildlife (water for drinking and habitat), and the various recreation (e.g., springs recreation) and cultural (former home sites for indigenous people) are summarized in Table 1, along with groundwater quality, surface water quality and quantity, and habitat. Change in potentiometric surface level, Floridan aquifer recharge data, and soils data were used to characterize the groundwater quantity resource functions (Table 2). While discharge to surface waters is listed as a groundwater surface function, data specific to the base flow contributions in the watershed were unavailable.

To develop groundwater targets, areas with groundwater levels that remain relatively unimpacted (at historic levels) and in which permeability has not been eliminated (not urbanized) are considered for conservation, while the areas with declines in groundwater levels or are affected by development are considered for restoration. Groundwater data were evaluated as to whether groundwater levels had changed with respect to historic conditions, whether land surface conditions were in good (close to historic) conditions, and whether soil conditions were appropriate for recharge.

Data for each groundwater attribute were ranked and then combined to produce the groundwater quantity data layer (Figure 6). Numerical rankings were assigned to the relevant attribute, e.g. change in potentiometric elevation from pre-development to 2008, for each layer (Table 3). The potential for recharge data layer was generated by combining the recharge and discharge data from the Floridan aquifer system (SWFWMD 2003) with 2009 Florida Land Use Cover Forms and Classification System (FLUCFCS) data. Recharge of the Floridan aquifer is necessary to maintain both groundwater and surface water levels (PBSJ 2009 and 2010a). The FLUCFCS data were identified as either developed (e.g. residential, transportation) or undeveloped (e.g. wetlands, agriculture). Priority rankings were assigned using both the Floridan recharge data and developed or undeveloped land use classification categories. All pixels with no recharge (discharge/ recharge <1) were assigned a rank of “0” indicating no existing impact on groundwater quantity. Developed areas that have the potential for recharge were assigned a priority ranking of “-5”, indicating restoration. Undeveloped areas with recharge were assigned a priority ranking of “+5”, indicating conservation is recommended to maintain groundwater recharge. The effects of water withdrawals on groundwater were, then, evaluated across the watershed using potentiometric surface changes. Although the Southwest Florida Water Management District (SWFWMD) uses models such as the District Wide Regional Model, DWRM or DWRM2 to examine potential effects of individual wells and well fields on groundwater for permitting purposes, results of these models are permit-specific and do not address the combined effects of multiple or adjacent wells or well fields.

Similar to the potential recharge data layer, 2009 FLUCFCS data were used to identify locations which have resulted in modified soil infiltration rates due to development. Priority rankings were assigned using both the soils classification data (USDA-NRCS 1990) which indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting and developed or undeveloped land use classification. All pixels that had soils with low infiltration rates (Class C, D and B/D) were assigned a rank of “0” indicating that there is no existing impact on groundwater quantity. Developed areas which have the potential for high soil infiltration rates (Class A and B) were assigned a priority ranking of “-5” indicating restoration. Undeveloped areas with the potential for high soil infiltration rates were assigned a priority ranking of “+5” indicating conservation is recommended to maintain groundwater recharge.

The change in potentiometric surface was estimated as the difference between the pre-development and 2008 potentiometric surfaces using data from SWFWMD (SWFWMD 2002 and 2008).Locations with no change in potentiometric surface were assigned a rank of “+5” indicating conservation is appropriate. For locations in which a decline (negative change) in potentiometric elevation occurred, a rank of “-5” was assigned, indicating that a loss in storage and a need for restoration. The groundwater quantity data layer displays areas suitable for restoration to conservation, on a scale of “-5” to “+5” (Figure 6), based on the integration of the individual data layers (e.g., potential recharge and soils). For example, a particular location that was assigned a “-5” for potential recharge (developed, but with recharge characteristics), a “-5” for modified infiltration (e.g. paved surface), and a “-5” for change in potentiometric surface elevation (historic decline) would have an average rank of “-5” (-15/3 =-5) and would therefore be indicated by dark brown “restoration” in the groundwater quantity resource function layer.

Patterns in the groundwater quantity resource function layer reflect changes in potentiometric surface elevations, patterns in urbanization, and groundwater recharge in the watershed (refer to Appendix B for individual data layer maps for comparison).For example, recharge is greater in the middle portion of the watershed and less in the uppermost and lower quarter of the watershed. Areas that did not exhibit groundwater declines appear green and tan in the northwest and southeast portions, respectively, of the watershed (Figure 6).The influence of urbanization on potential recharge in the City of Winter Haven (dark brown) corresponds to less recharge, while lighter brown areas show the influence of agriculture and more rural development on recharge, i.e., greater recharge to the Floridan aquifer. Similarly, altered soils infiltration rates show as restoration (brown) targets, while areas with high infiltration rates, high recharge potential, and unaltered potentiometric surface levels are indicated as conservation (green) targets.

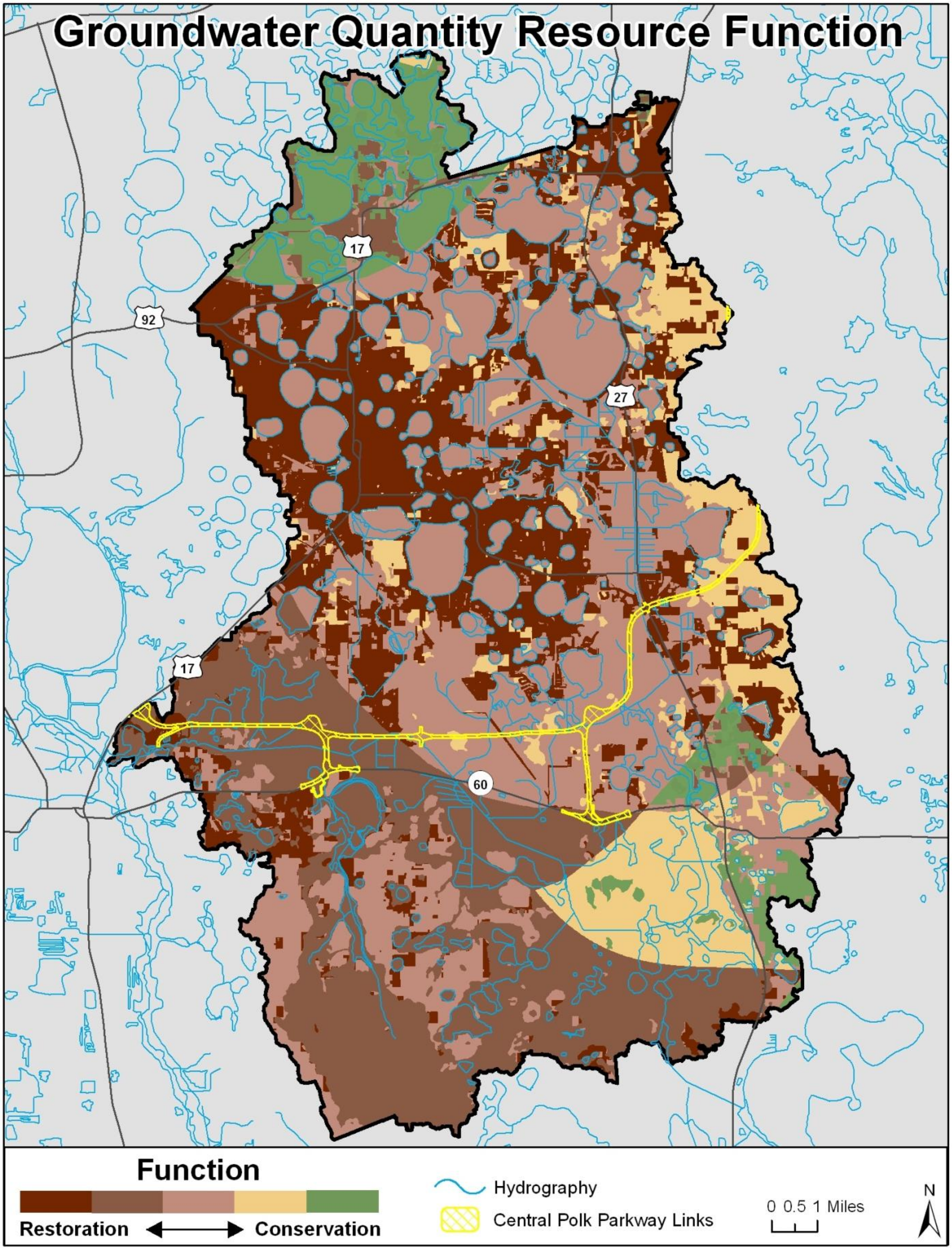
Table 2. Data representing groundwater quantity resource functions.

Data Layer	Description	Source
Potential recharge	Effect of urbanization on Floridan recharge rates	Atkins 2011
Modified infiltration	Impact of urbanization on soil infiltration rates	Atkins 2011
Change in potentiometric elevation	Displays the change in potentiometric elevation from pre-development to 2008 development	Atkins 2011

Table 3. Ranking scale used to assign priority for the groundwater quantity resource function.

Attribute Used in Ranking	Ranking
Potential Recharge	
No recharge	0
Development with recharge	-5
No development with recharge	5
Modified Infiltration	
Low-infiltration soils	0
Development with high-infiltration soils	-5
No development with high-infiltration soils	5
Change in Potentiometric Surface Elevation	
0 change (no change)	5
10 feet decrease	-5
20 feet decrease	-5
30 feet decrease	-5

Figure 6. Composite groundwater quantity resource function layer.



2.2. Groundwater Quality

Groundwater contributions can make up as much as 80 percent of the base flow to some surface waters in Florida (Florida Department of Environmental Protection, FDEP, 2011) and emphasize the importance of the link between ground and surface water quality. Studies of the effects of stormwater on groundwater quality have also indicated potential problems (e.g., chlorides, pesticides, pathogens, and heavy metals) depending on mobility and infiltration methods used (Pitt et al. 1999). Groundwater contamination associated with surface water runoff is considered rare in residential areas where land surfaces were permeable, but more common in commercial and industrial areas. Identifying potential areas for groundwater restoration can provide a means of improving water quality in strategic locations and/or avoiding costly clean-up or remediation efforts.

GIS data layers were insufficient to evaluate potential conservation and restoration targets and impaired groundwater conditions in the watershed. The data gaps for evaluating groundwater quality were conspicuous, unlike other resource functions examined. The process of data selection, data ranking, and application for groundwater quality is outlined in Figure 5. The data layer for the SWAAs identifies specific locations at which public water supplies are monitored to identify and assess any potential sources of contamination in the vicinity of water supply (FDEP 2008, Table 4). Therefore, these locations were buffered by an additional 500 feet of area and were assigned a value of “+5” based on the assumption that wells used for public water supply have good water quality (FDEP 2008). Areas outside the buffers were assigned a neutral zero value, given that the groundwater quality is not characterized. While these data were insufficient to characterize the watershed, they may provide a means of assigning additional “weight” to alternatives for scenario evaluation (see section 6 for further detail on weighting alternatives). For example, groundwater recharge via rapid infiltration basins (RIB) would not be considered an alternative where groundwater contamination has been documented. The data layer can still be used with the appropriate caveats.

Resource Conservation and Recovery Act (RCRA) data provide specific site locations at which hazardous waste is handled (U.S. Environmental Protection Agency (EPA) 2011). These locations were assigned a rank of “-5” indicating the need for restoration.A500-foot buffer was established around each RCRA site. The composite groundwater quality resource function displays areas suitable for restoration or conservation (Figure 7). The available data for groundwater quality indicate numerous locations where data are available, but are not indicative of any particular water quality patterns. RCRA sites are typically associated with roads and urbanized areas due to industrial land uses and associated testing and more rural sites are often not identified until testing for further land development is required. Preliminary evaluation of the groundwater quality resource function clearly identified a data gap that precludes the ability to identify conservation or restoration targets except in specific locations in the watershed near public water supply wells or RCRA sites.

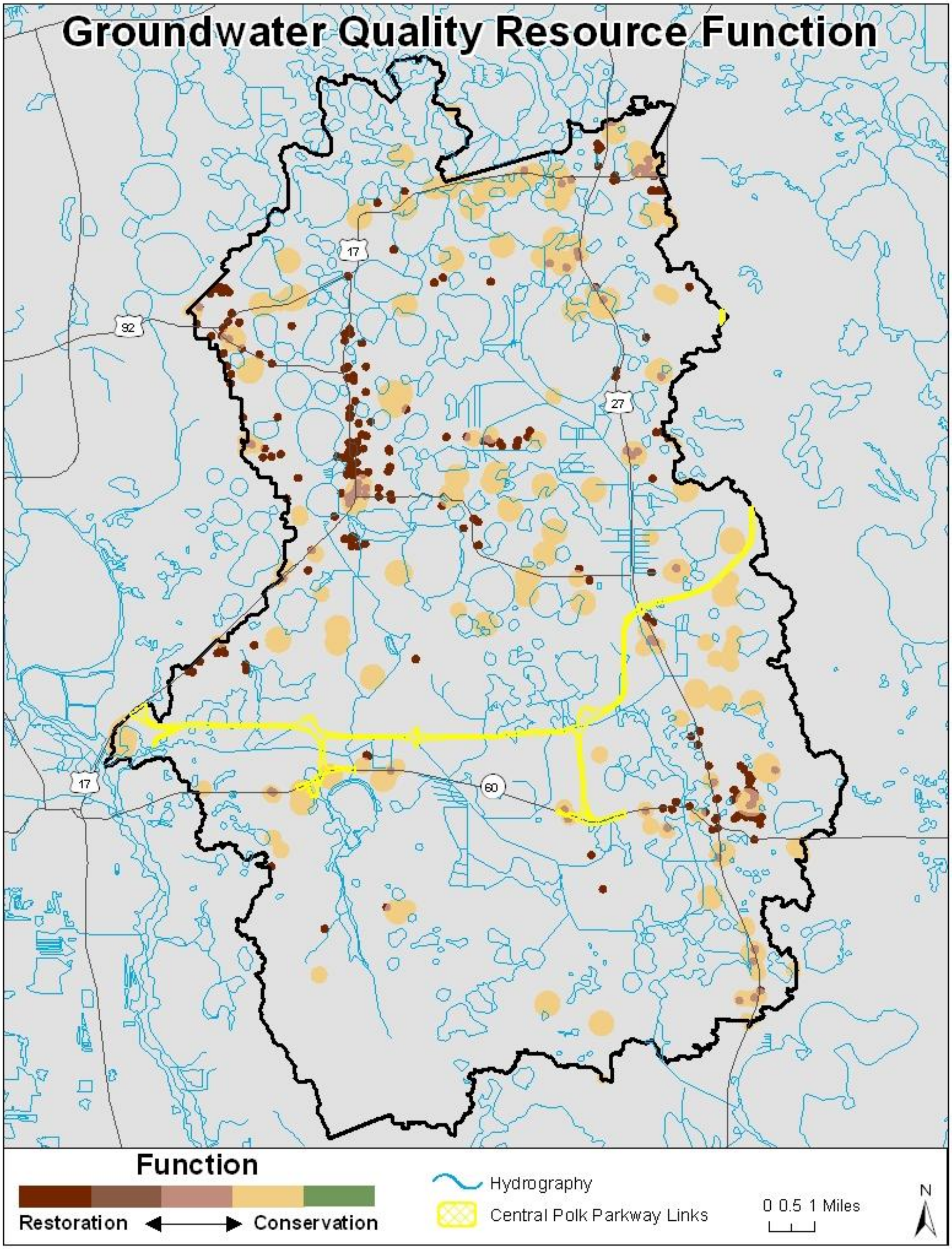
Table 4. Data representing groundwater quality resource functions.

Data layer	Description	Source
SWAAs	FDEP source water assessment for public water systems (potential contamination near water supply	FDEP2008
RCRA	Sites regulated by the RCRA (hazardous waste)	EPA2011

Table 5. Ranking scale used to assign priority for the groundwater quality resource function.

Attribute Used in Ranking	Ranking
SWAAs	
SWAA with 500-foot buffer	5
Areas not associated with SWAA or buffer	0
RCRA	
Areas not associated with RCRA site or buffer	0
500 feet buffer around RCRA site	-5

Figure 7. Composite groundwater quality resource function layer.



2.3. Surface Water Quality

Surface water quality in the City of Winter Haven is the subject of the recently completed *Winter Haven Chain of Lakes Water Quality Management Plan*(Atkins 2010), which should be referred to for a detailed evaluation of lake water quality, impairment status, and existing and proposed management strategies for the lakes. The importance of water quality and its interactions with surface water, habitat, and groundwater quantity are detailed in the management plan and only briefly presented here in the context of data selection and ranking. Water quality restoration and conservation areas, however, may be used as part of future work efforts, in combination with projects proposed in the management plan, in the development of restoration and conservation strategies and an evaluation of the most beneficial strategies. The relationships between surface water quality function and benefits were summarized in Table 1 and emphasized the importance of water quality to potable water supplies, fish and wildlife habitat, and fishable/swimmable waters for recreation.

Relevant GIS data layers for the surface water quality resource function were compiled and summarized (Table 7) and numerical rankings were assigned to the relevant attribute for each layer (Table 8). The areal extent of the surface water quality data layer includes historical and current wetlands and lakes as well as areas of potential storage identified in the Peace Creek Watershed Management Plan Draft Alternatives Report (2006).The data layers used to develop the surface water quality resource functions are also mapped in Appendix B. The process of water quality data selection and application was summarized in Figure 3. The water quality status data layer was generated by evaluating water quality from the Group 2, Cycles 1 and 2 verified impaired waters list developed by FDEP with regard to the guidance provided by EPA's numeric nutrient criteria (NNC).Using the waterbody identification (WBID) list from the study area, FDEP designated impairments based on elevated nutrients, fecal coliform bacteria, or dissolved oxygen. In order to evaluate compliance with NNC, data were downloaded from the Impaired Waters Rule (IWR) Run 43 database by WBID. The data were analyzed using the NNC guidelines; each WBID was identified as impaired, unimpaired, or containing insufficient data to determine impairment based on total nitrogen or total phosphorus concentrations. Impaired data represent a change from historic conditions, while no impairment indicates no change. WBIDs designated impaired by either FDEP or using the NNC method were assigned a value of "-5" indicating that water quality is impaired and restoration of the water body is appropriate. WBIDs classified as unimpaired through both the FDEP and NNC screening process were given a rank of "+5" indicating that current water quality is unimpaired and conservation of water quality conditions is appropriate. If insufficient data were available to complete the NNC analysis and the WBID was not declared impaired by FDEP, the WBID was assigned a rank of "0" indicating that data were insufficient data to evaluate restoration or conservation conditions.

The "Significant Surface Water"(SSW) GIS layer identifies areas currently in a relatively natural condition (FNAI 2010) that arein the vicinity of (i.e. contribute surface water runoff to) a surface water feature that has state-wide significance (www.landscope.org). Absence of the SSW designation does not preclude the presence of significant resources, only that the site has been evaluated and designated as such. The SSW map layer appears consistent with land uses proximate to lakes, i.e. developed lakes are not listed and undeveloped wetlands and lakes are listed. The SSW includes is a combination of eight water resource data layers: Special Outstanding Florida Water (OFW) rivers as defined by DEP, other OFWs (on conservation lands), OFW lakes and Aquatic Preserves, coastal surface waters, the Florida Keys, springs, rare fish basins, and water supply sources. Drainage basins designated as SSW were assigned a rank of "+5" , indicating conservation of SSWs. Areas not designated as SSWs were assigned zero ranks, indicating absence of designation.

The ridge/valley lake layer is based on the premise that the lake water quality can be attributed to the geographic location and surrounding watershed characteristics. Ridge lakes are typically associated with sandy areas with high groundwater recharge at higher elevations when compared with valley lakes, which are often dominated by surface water flows and located at lower elevations. Ridge lakes typically have herbaceous vegetation along shorelines compared with forested wetlands that often characterize valley lakes. Ridge lakes, particularly those with a history of point source discharges, can be more susceptible to impacts from nutrient-enriched bottom sediments when compared with valley lakes (i.e. see Bachman *et al*. 2000). Sediments disturbed by wind or wave action can reintroduce nutrients into the water column and cause phytoplankton blooms. For valley lakes, lower lake levels can "disconnect" the lake from historical swamp shorelines, reducing the benefits of wetland-derived tannins that buffer the effects of increased nutrients (Atkins 2008).

Historically, virtually all of the rainwater that fell on the sandy ridge areas in the Peace Creek watershed percolated into the soils that are characterized by high infiltration rates (approximately 6.0 inches/hour, USDA/SCS Polk County Soil Survey 1990), while excess water was stored in the lower valley wetlands. During the dry season, ridge lakes were historically maintained by groundwater from the sandy surficial aquifer, which is one of the highest recharge zones for the Floridan aquifer in the Southern West Central Groundwater Basin. Urban development in the Winter Haven Chain of Lakes (WHCL) occurred primarily on soils that have high infiltration rates. Consequently, rainfall that formerly infiltrated these high recharge areas is now surface water runoff. Low color lakes (<40 PCU) with less than 10 percent forested wetlands within the 500 foot buffer of the lake are likely “ridge” lakes and as such are not influenced by tannins. The percent developed and undeveloped land within the watershed of each ridge lake was reviewed. Ridge lakes (color < 40 PCU) in which greater than 50 percent of the watershed was developed were assigned a rank of “-5” indicating that restoration is recommended to re-establish stormwater infiltration. Ridge lakes in which less than 50 percent of the watershed was developed were assigned a rank of “+5” indicating that conservation is recommended to maintain stormwater infiltration.

Valley lakes with high levels of tannins (color) are considered to be more tolerant of elevated nutrient availability than lakes with lower levels of tannins (PBS&J 2010a).In order to maintain the tannin influence within a lake, a target of 50 PCU color and 10–20 percent forested wetlands within the 500-foot buffer of the lake is recommended (PBS&J 2010a and b).For WBIDs classified as lakes, the percent of forested wetlands within a 500-foot buffer of the lake was calculated. High color lakes (>50 PCU) and more than 10 percent forested wetlands within the 500-foot buffer of the lake were assigned a rank of “+5.” These lakes are likely “valley” lakes with a connected forested wetland. Low color lakes (<50 PCU) and more than 10 percent forested wetlands within the 500-foot buffer of the lake were assigned a rank of “-5.”These lakes are likely “valley” lakes in which the hydrologic connection between the lake and adjacent wetlands is absent. High color lakes (>50 PCU) and less than 10 percent forested wetlands within the 500-foot buffer of the lake were assigned a rank of “-5.”These lakes are likely “valley” lakes in which the hydrologic connection between the lake and adjacent wetlands is altered. The composite surface water quality resource function displays the integration of each GIS layer to identify areas suitable for restoration to conservation (Figure 8).Lakes without color data were assigned a value of “0” indicating that restoration or conservation could not be determined. Water quality status appears to have influenced the distribution of conservation and restoration features displayed in the surface water quality resource function layer.

When possible, the ridge/valley lakes layer was displayed by watershed to incorporate the influence the adjacent contributing watershed can have on water quality. While watershed delineations have been previously completed as part of the *Winter Haven Chain of Lakes Water Quality Management Plan* (PBS&J 2010b), 29 delineations were re-evaluated and an additional 68 have been subsequently completed for this project.

The surface water quantity data layer displays areas suitable for restoration to conservation, on a scale of “-5” to “+5” (Figure 3), based on the integration of the individual data layers (e.g., water quality status, significant surface water).For example, a particular location that was assigned a “+5” for water quality status, a “+5” for significant surface water, and a “+5” for ridge/valley lakes would have an average rank of “+5” (15/3=+5) and therefore be indicated by green, “conservation,” within the surface water quantity resource function layer.

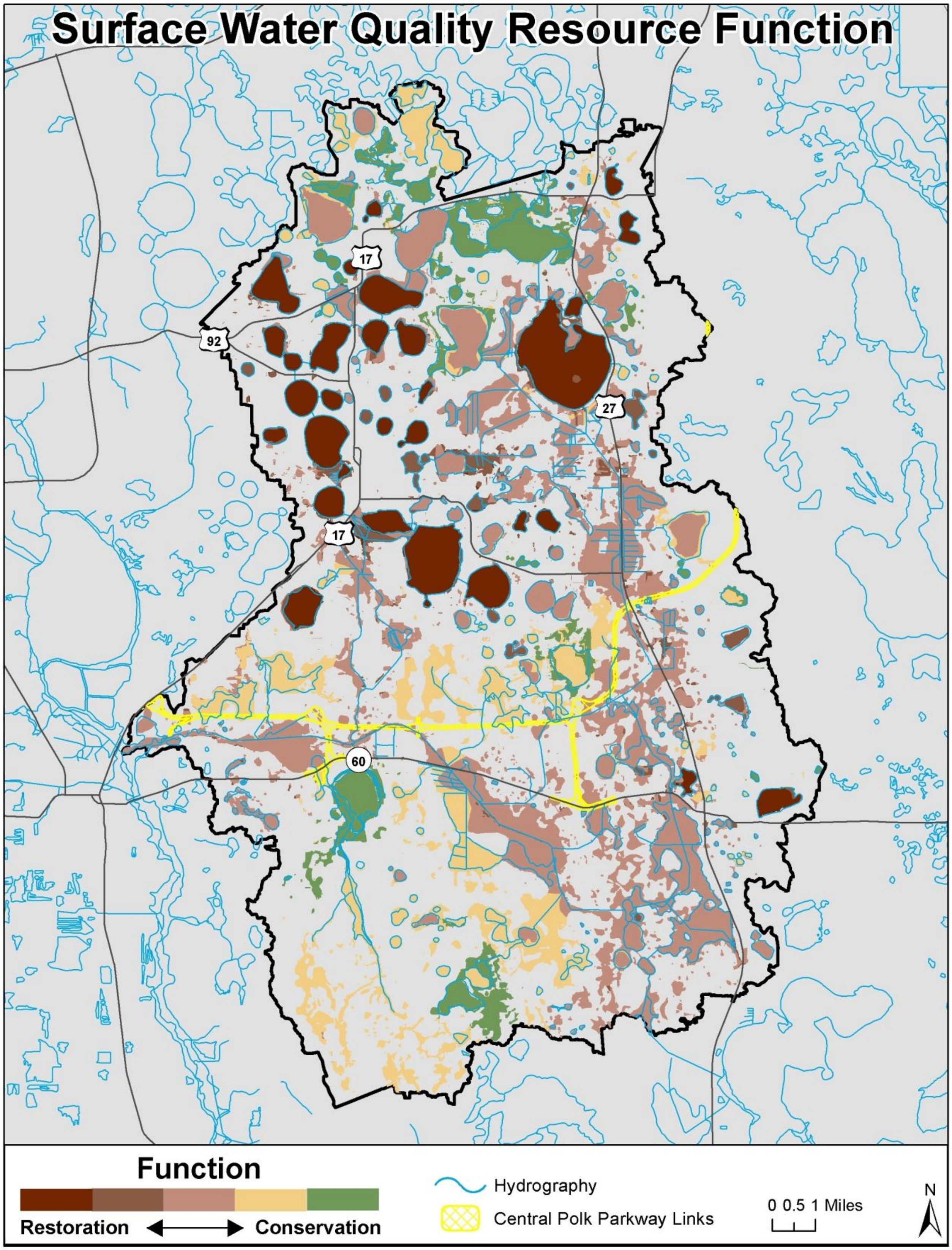
Table 7. Data representing surface water quality resource functions.

Data Layer	Description	Source
Water quality status	Identifies impaired or unimpaired water quality conditions by WBID as declared by FDEP or NNC guidance	Atkins 2011
Significant surface water	Identifies areas that have statewide significance for land acquisition to protect surface waters with good water quality and those that are currently in a relatively natural condition	FNAI2010
Ridge/valley lakes	Lake water quality can be attributed the geographic location (ridge versus valley) and surrounding watershed characteristics (development or forested wetlands)	Atkins 2011

Table 8. Ranking scale used to assign priority for the surface water quality resource function.

Attribute Used in Ranking	Rank
Water Quality Status	
Impaired WBID designated is classified as impaired by either FDEP or using NNC method	-5
Unimpaired if not classified as impaired by both FDEP and using NNC method	5
Insufficient data to complete NNC analysis and not declared impaired by FDEP	0
Significant Surface Water	
0	0
Priority 1	5
Priority 2	5
Priority 3	5
Priority 4	5
Priority 5	5
Priority 6	5
Priority 7	5
Ridge/Valley Lakes	
Lakes with low color (<40 PCU), >50% developed watershed	-5
Lakes with low color (<40 PCU), <50% developed watershed	5
Lakes with low color (<50 PCU), >10% forested wetlands in 500-foot buffer around lake	-5
Lakes with highcolor (>50 PCU), <10% forested wetlands in 500-foot buffer around lake	-5
Lakes with highcolor (>50 PCU), >10% forested wetlands in 500-foot buffer around lake	5
Lakes with no color data	0
Streams	0

Figure 8. Composite surface water quality resource function layer.



2.4. Surface Water Quantity

The surface water quantity resource function represents the change in surface water storage between historic and current conditions. Restoration is a measure of historical loss of water storage and does not provide a measure of the overall quality of, for example, a degraded wetland that still provides storage but has been subject to agricultural practices for decades (and should be examined with respect to habitat as well). Therefore, this resource function represents potentially recoverable water storage in the case of restoration targets and opportunities for water storage management in the case of conservation targets. Connectivity is difficult to measure but is important when considering the historic surface water connections. While connectivity is not measured for surface water, it can be superimposed on the targets map to examine its influence. Connectivity is a measure of habitat, however, and is typically consistent with surface water connections.

The areal extent of the surface water quantity data layer includes historical and current wetlands and lakes, including wetlands associated with water conveyances such as streams and creeks, floodplain wetlands, isolated wetlands, and National Wetlands Inventory (NWI) wetlands (which include seasonally inundated wetlands). The data layer does not include Federal Emergency Management Agency (FEMA) floodplains. The FEMA floodplains differ from NWI and wetland floodplains in that FEMA floodplains are designated for flood risk and insurance purposes (based on the one percent annual flood occurrence or "100-year floodplain"). The FEMA floodplain is typically broader than floodplain wetlands because a one percent flood occurrence is inadequate (brief duration) to support wetlands and therefore provided little to no water storage. The FEMA floodplain designations are regularly updated as land uses and flood risks change and may reflect increases in impervious surface that result in flooding. In the Peace Creek watershed, and in the larger Peace River watershed, the historic wetlands closely follow the FEMA 100 year floodplain, probably due to the sharp increase in elevation at the 100 year flood elevation.

The data layers used to develop the surface water quantity resource function layer are listed and described in Table 9 and numerical rankings assigned to the relevant attributes are listed in Table 10. Individual data layers are mapped in Appendix B for comparison with resource function layer maps. The process of data selection, ranking, and application is summarized in Figure 9. For example, the change in surface water storage was calculated from a comparison of hydroperiods under historic and current land use/ land use using GIS and follows the approach used for the Natural Systems Model that the South Florida Water Management District uses to model pre-drainage conditions in the Everglades (SFWMD 2010) and refined based on the methods presented for the Collier County Watershed Management Plan (Atkins 2010).

Hydrology scoring represents the functional value of a parcel of land based on the degree to which the parcel retains the same hydrological characteristics as its historic reference condition. Hydrologic conditions (hydroperiod) are estimated based on the typical range of depth (inches) and duration (days) of inundation of the vegetation community. No change from historic conditions would result in a score of "+5", while total loss of hydrology (e.g. a cell dominated by a historic condition wetland or open water body but which now experiences no inundation) would result in a score of "-5". The hydrology score was applied on a 750 feet x 750 feet cell basis.

The hydrology score for a cell/parcel is based on the ratio of the existing depth and duration in comparison to the historic condition, adjusted to a scale of "-5" to "+5". For instance, a site that historically had an average hydroperiod of six months and an average inundation of 12 inches, but which currently is inundated for only two months at an average depth of four inches (i.e. the site currently experiences one-third of the depth and duration of the historic condition for that site), would have a hydrology score of "-1.67". More simply, a cypress swamp that was converted to an urban land use would be represented by a loss of storage and have a rank of "-5", while a cypress swamp that retained its hydrology would have a rank of "+5".

Surface water quantity restoration and conservation targets are mapped in Figure 9. The most conspicuous feature is a general pattern of ridge lakes (along the Winter Haven Ridge) designated as predominantly restoration (brown) lakes and the "valley" lakes (on the adjacent, lower, Polk Upland) designated as predominantly conservation (green) lakes. This is consistent with the result of previous studies of the Winter Haven Lakes that point to the groundwater dependence of the ridge lakes and the changes in these lakes as a consequence of the declining aquifer. The valley lakes have a greater surface water influence, which is also reflected in the more elongate shapes, compared with the round ridge lakes.

The shift from native uplands to urban development represents a change in surface water storage in the watershed, although the urban areas actually had greater storage. Consequently, urban areas that were formerly native uplands were assigned a value of “0” to avoid the appearance that “restoration” was recommended solely based on a gain in surface water storage. In addition to mapping the changes in surface water from historic to current conditions, the loss of storage represented by the changes was calculated. For example, a conversion from wetlands such as cypress swamp and wet prairie to agriculture and urban land uses represents a particular loss of surface water storage that may be restored, although restoration of agricultural lands is more likely than restoration of urban lands.

Using the numbers in Table 11, a total of 2,124 acre-feet of historic water storage in cypress swamp has been lost due to conversion to many different land uses (e.g. 90 acre-feet of storage to agriculture, 60 acre-feet to golf course, 618 acre-feet to urban development). Similarly, 6,596 acre-feet of former lake/open water storage has been lost due to conversions to other land covers/uses (e.g. 101 acre-feet of historic lakes converted to agriculture). Overall, the results of this analysis indicate that an estimated 20,815 acre-feet of surface water storage have been lost, primarily due to a conversion of wetlands and lakes to developed (urban, agriculture, and golf courses) land uses (Table 11). These losses were due primarily to loss in forested wetlands (cypress swamp and swamp forest, 12,904 acre-feet) and open water/lakes (6,596 acre-feet).

In terms of restoration opportunities, some of the conversions may represent opportunities to regain water storage. For example, a total of 10,061 acre-feet of former wetlands and open water were lost due to conversions to pasture and bare ground (Table 11) and represent a loss of the same amount of storage that may be seen as a restoration opportunity.

Numerous lakes are mapped as restoration (brown) due to loss of storage, while some are mapped as conservation (green) due to gains in storage. Losses and gains are based on comparisons between historic and existing land use cover (i.e. areal extent of lakes) and typical changes in depth associated with changes in land use. For example, a loss of 10 acres of a lake as a result of a shift from open water to urban would represent a greater loss of storage than a shift to a marsh or forested wetland as a result of the differences in water depths. Although changes in lake depth have not been evaluated for many lakes, analyses completed in a previous study (Atkins 2009) indicate an average decline of five feet in lake levels in the Winter Haven Chain of lakes. Lake data for the 1850s are not available from the SWFWMD website, but recently, the SWFWMD provided data prepared for the watershed that estimate 1850s land cover using 1927 soils maps. However, the soils maps are not pre-development and differences between the 1927 and 1940s land cover maps appear negligible. Consequently, the existing historic (circa 1940s) and current (2009) data are considered the best data available for this project.

Table 9. Data representing surface water quantity resource functions.

Data Layer	Description	Source, Date
Historic land use	Historic land use against which to measure changes in land use	Atkins, as developed for Peace River Cumulative Impacts Study
Current land use	Current land use for comparison with historic land use	SWFWMD 2009
Hydrology	Depth and duration of natural communities to evaluate changes in surface water storage between current and historic land use.	Duever *et al.* 1986

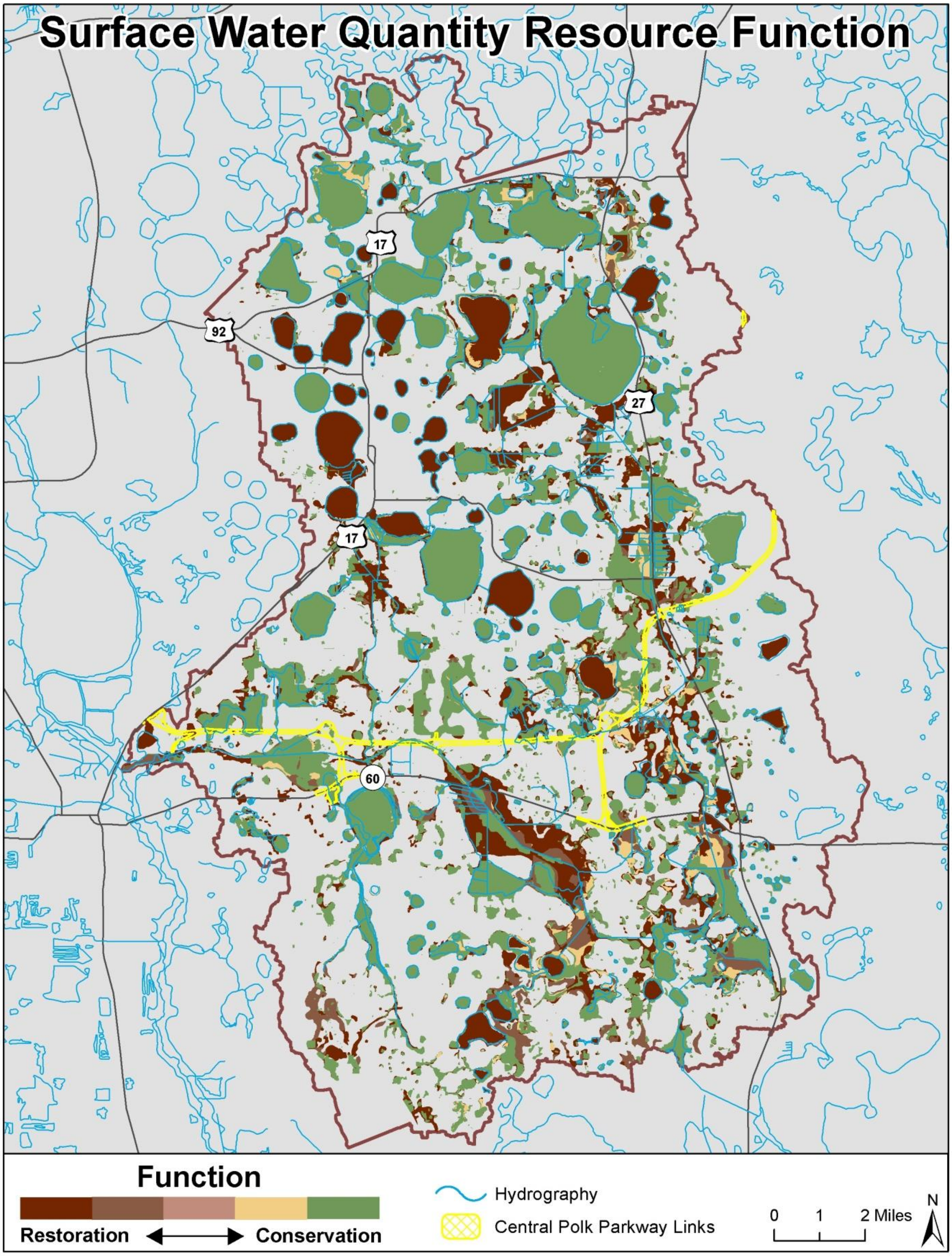
Table 10. Ranking scale used to assign priority for the surface water quantity resource function.

Attribute Used in Ranking	Rank
Change in surface water storage	
Loss/gain in hydroperiod	-5
No change in hydroperiod	5

Table 11. Calculated changes in surface water storage from historic to current land use/land cover conditions (acre-feet).

		Historic Wetland and Lakes Land Cover					
	Land Cover Class	Cypress	Freshwater marsh	Mesic hammock	Swamp forest	Lakes	**Total**
Current Land Use/Land Cover	Agriculture	-90	-91	0	-344	-101	**-626**
	Cypress	0	0	0	-39	-2	**-41**
	Freshwater marsh	555	0	0	-936	-4,156	**-4,537**
	Golf course	-60	-37	0	-258	-62	**-417**
	Mesic flatwood	-136	-128	0	-108	-20	**-392**
	Mesic hammock	-331	-37	0	-517	-77	**-962**
	Pasture andbare ground	-2,742	-1,189	0	-5,811	-319	**-10,061**
	Swamp forest	936	39	0	0	-187	**788**
	Urban	-618	-421	0	-1,915	-1,460	**-4,414**
	Lakes	859	839	0	930	0	**2,628**
	Wet prairie	-497	-291	0	-1,782	-211	**-2,781**
	Total	**-2,124**	**-1,315**	**0**	**-10,780**	**-6,596**	**-20,815**

Figure 9. Composite surface water quantity resource function layer.



2.5. Habitat

Three GIS data layers were considered relevant for evaluating habitat targets. The relationships between and among the habitat, surface water quality and quantity, and groundwater quality and quantity were summarized earlier in the resource benefit function matrix in Table 1. Data for each habitat attribute were ranked to develop individual data layers and then the layers were combined to form the habitat resource function layer. The habitat layer represents the relationship of land cover and species populations, which represent the habitat resource function, with the resource benefit, as represented by fish and wildlife habitat. While habitat may be considered a water resource benefit based solely on appearance (i.e., marshes, cypress swamps, and oak forests), the condition of a habitat is a reflection of the health of the more physical ground and surface water functions. The GIS tool is presently configured so that each of the resource function layers (e.g., habitat, groundwater quantity) can be turned off. This is especially useful for habitat, which provides a means of evaluating the potential for restoration beyond merely the physical impacts (i.e., surface water storage without a vegetation component has a tremendous evaporative water loss), while a high-recharge area without native vegetation may have a tremendous impact on stormwater runoff. These examples emphasize again the need to examine restoration and conservation targets as single layers and in different combinations to ensure a proposed project is developed within the appropriate framework.

The influence of habitat on water resources is well documented (see Smerdon et al. 2009 for a good review of groundwater effects). Habitat connectivity typically reflects surface water connectivity, as described previously. Habitat also affects water quality via natural treatment wetlands and drives water quantity via evapotranspiration. Consequently, habitat may serve as a proxy for some local factors that are not available in a data base (e.g. condition of water resource) and, here, is used as an additional relative measure of the health of the water function that may otherwise go un-quantified. While the value of wetlands as surface water storage and water quality treatment is readily apparent, the value of upland forested areas may not be so apparent. However, upland forested areas improve water quality via nutrient assimilation (uptake) as well as phyto-remediation (toxin assimilation). Removing forested uplands reduces evapotranspiration, increases the amount of rainfall percolating through the soil to the aquifer, and can raise groundwater and/or surface water levels (Bliss andComerford2002, others), as well as increase runoff (Moore and Wondzell 2005) and the corresponding need for flood protection (Smerdon et al. 2009). Vegetation also mediates rainfall by returning water to the atmosphere via transpiration. One study (Chan et al. 2006) concluded that while developing targets purely for biodiversity protection is not likely to be adequate for biodiversity, it would protect an “impressive” number/extent of ecosystem services. Therefore, habitat was included as a resource function for the purposes of developing restoration and conservation targets. The habitat data layers used to develop the habitat resource function map were mapped individually and provided in Appendix B.

One component of the habitat resource function layer was based on the Strategic Habitat Conservation Areas (SHCAs). SHCAs were developed as a means of representing the potential presence of suitable habitat for one or more terrestrial vertebrate species that likely require this area to ensure long-term survival of key components to Florida’s biological diversity (Cox *et al.* 1994). SHCAs are themselves a result of integrating multiple types of information, including protected species, existing land cover, adjacent land cover, number of acres, and other data. Therefore, all locations included in SHCA data layer were assigned values of “+5” indicating that conservation was an important consideration.

Historic wetland and native uplands were digitized using 1940s aerial photography as part of the previously developed Peace River Cumulative Impact Study (PRCIS) (Atkins 2007). While many wetlands were already drained by the 1940s, aerial photography is not available prior to the 1940s (aerial photography was first used by the military in World War I and commercial use began about 1935). All historic wetlands and native uplands identified using the PRCIS coverage were assigned the ranking of “+5” representing an undeveloped (considered unimpacted) habitat condition which may provide conservation opportunities (Table 13). Similarly, a ranking of “+5” was assigned to native uplands, wetlands and water 2009 FLUCFCS data for conservation as these land uses types represent habitat. In contrast, residential, commercial, transportation, industrial and institutional FLUCFCS data were assigned “-5” to indicate restoration due to the loss of habitat function. The composite habitat resource function displays the integration of each GIS layer to identify areas on a scale from restoration (altered habitat) to conservation (unaltered habitat) (Figure 10). For example, a particular location that was assigned a “+5” for SHCA, a “+5” for both historic and existing land cover (unaltered condition), would have an average rank of “+5” (15/3=5) and would therefore be indicated by green (conservation) within the habitat resource function layer. The dark brown (restoration) portions of the map is solely influenced by development as they are not identified as SHCA and historic land use data are unavailable for evaluation.

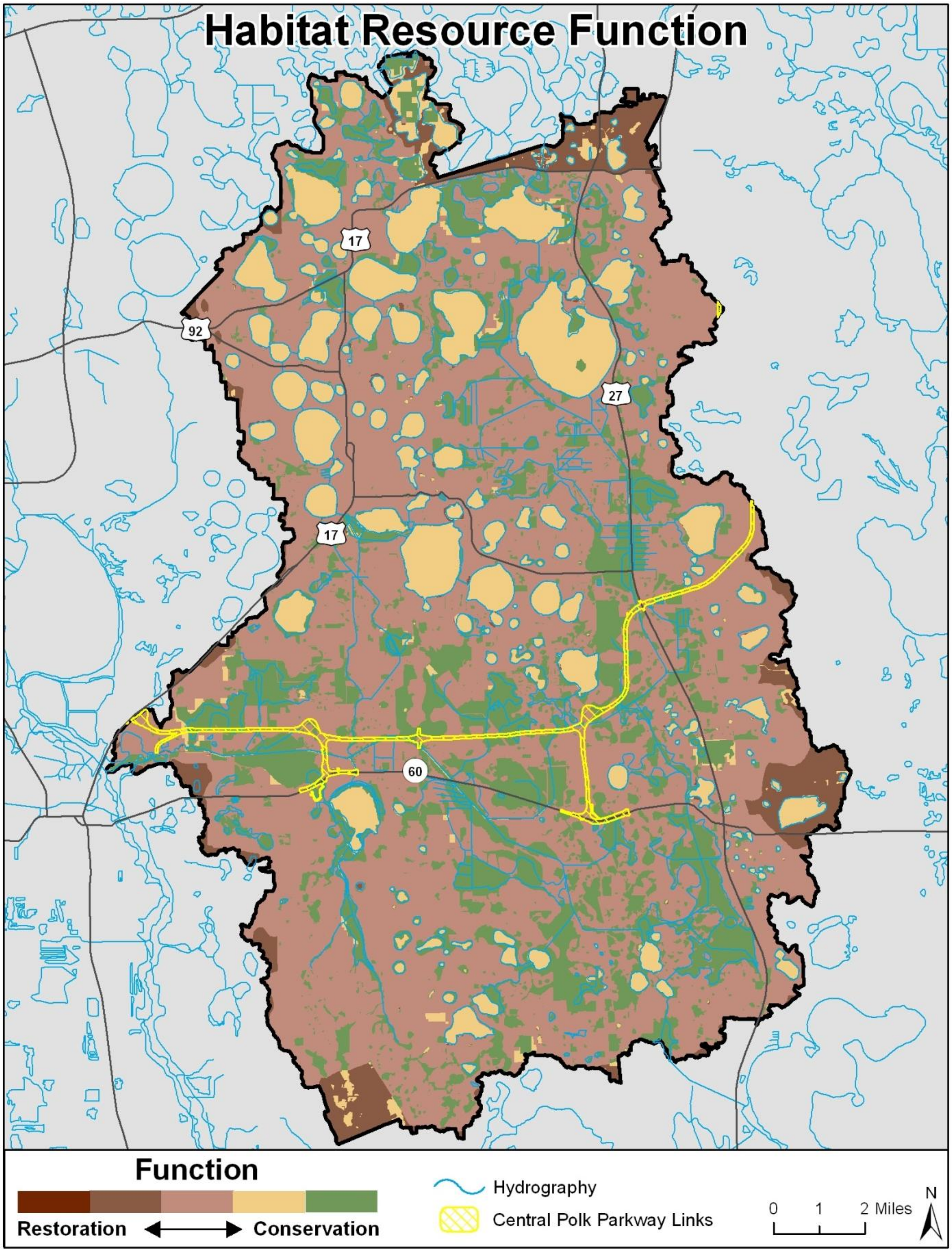
Table 12. Data representing habitat resource functions.

Data Layer	Description	Source
SHCA	Habitat conservation areas important to continued survival of key species	FWC 2009
Historic Wetland and Native Upland Habitat	Historic wetlands and native upland	Atkins 2007
FLUCFCS	Current land use and land cover	SWFWMD 2009

Table 13. Ranking scale used to assign priority for the habitat resource function.

Attribute Used in Ranking	Rank
SHCA	
Priority 1: State Rank 1 and Global Rank 1–3	5
Priority 2: State Rank 1 and Global Rank 4–5 or State Rank 2 and Global Rank 2–3	5
Priority 3: State Rank 2 and Global Rank 4–5 or State Rank 3 and Global Rank 3	5
Priority 4: State Rank 3 and Global Rank 4	5
Priority 5: State Rank 3 and Global Rank 5 or State Rank 4 and Global Rank 4	5
Historic Wetlands and Native Uplands	
6170 - Mixed Wetland Hardwoods	5
6210 - Cypress	5
6250 - Wet Pinelands/Hydric Pinelands	5
6300 - Wetland Forested Mixed	5
6400 - Vegetated Non-Forested Wetlands	5
6410 - Freshwater Marshes/Graminoid Prairie - Marsh	5
4110 – Pine Flatwoods	5
4120 – Longleaf Pine- Xeric Oak	5
4130 – Sand Pine	5
4140 – Pine -Mesic Oak	5
4230 – Oak-Pine-Hickory	5
4250 – Temperate Hardwood	5
FLUCFCS	
3000 - Upland Non-Forested	5
4000 - Upland Forested (excluding 4400)	5
5000 - Water	5
6000 - Wetlands	5
1000 - Urban and Built-up	-5
2000 - Agricultural	-5
4400 - Tree Plantations	-5
7000 - Barren Land	-5
8000 - Transportation, Communications, and Utilities	-5

Figure 10. Composite habitat resource function layer.



3. Data Gaps

The analyses undertaken in developing the conservation and restoration resource targets relied on available data. While the results of this analysis appear consistent with respect to dominant landscape features, such as the wetlands, geomorphic features (e.g., Lake Wales and Winter Haven ridges), and floodways, groundwater quality data are conspicuously sparse, primarily in terms of geographic distribution. Although numerous groundwater data layers are available (refer to Appendix A), they are site specific (confined to a particular well location) and typically characterize existing conditions rather than providing a means of comparison between existing and historical conditions. At least part of the gap in the availability of groundwater data is due to the focus on surface water programs at the federal and state levels, resulting in less support for groundwater protection and assessment programs (GWPC 2011).

A comprehensive hydrogeologic data base is critical to using groundwater quality as an indicator of conservation and restoration resources. The U.S. Geologic Survey (USGS) also points to issues of uncertainties due to sparse and inaccurate data, poor definition of stresses acting on the system, and errors in system conceptualization (Alley *et al*. 1999). The Florida Source Water Assessment and Protection Program is a major effort to identify potential threats to Florida's potable water supplies and data from that program were used for this project. However it is focused on contaminants and their cleanup rather than changes in water quality such as salt water intrusion, nutrients, or conductivity that may indicate other pressures of surrounding development. Consequently, groundwater data indicating contaminated sites or former contaminated sites are available for wells in which the contamination was or is monitored. Studies of the Everglades have, however, attributed groundwater quality contamination to land use patterns and changes in the watershed that could be controlled by best management practices (BMPs) (Munoz-Carpena *et al.* 2005), so resource targets representative of groundwater quantity or surface water quality, for example, may also be indicative of groundwater quality trends. The Federal government has implemented programs to address federally designated sites through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and RCRA programs. The RCRA sites are addressed for this project.

A second gap identified was the unavailability of survey data that would provide actual lake level data for determining changes in lake depths and area. Data were available for several lakes, but the missing data precluded including the lakes in the calculations of water storage, and the lakes were assigned zero values in the surface water quantity resource function map layers. The average decline in surface water levels of lakes evaluated in the Winter Haven Chain of Lakes is5 feet and is attributable to the construction of navigable canals constructed in the 1920sthat connected the lakes and decreased water storage (Atkins 2010b).Some lakes were lowered for agricultural or urban uses and wetlands were drained for agricultural uses. In contrast, evidence of water level declines in the Winter Haven Interior Lakes corresponded to an absence of navigable canals and groundwater recharge has not been documented (Atkins 2011). As such, each lake should be evaluated to identify the availability of potential surface water storage. Estimates of lake-level changes may be completed as part of future efforts by using aerial photograph and survey data to estimate lake-level changes, similar to the effort completed for the Winter Haven Basin Management Action Plan (BMAP) project. To accomplish this, survey data for the watershed should be reviewed, compiled, and used in combination with light detection and ranging (LiDAR) data to estimate elevation changes.

Models for surface water storage typically quantify the amount of water available as simply precipitation minus evapotranspiration (e.g., Chan et al. 2006, SFWMD 2000), without examining changes in land cover that may alter storage, with the exception of urbanized areas. In Florida, evapotranspiration is often presumed equal to rainfall due to the wide variability in measurements, omitting this component of water storage evaluations. For target development, an application of previous models (SFWMD Natural Systems Model) was used to calculate storage and rainfall components. Our GIS platform provides a means of estimating historical losses as well as identifying potential opportunities for ameliorating losses. Therefore, rainfall and evapotranspiration components were not considered data gaps for this analysis.

The effects of changes in regional rainfall patterns on surface and groundwater and long-term effects of climate change cannot be ignored. While beyond the scope of the present effort, future efforts may include pairing water conservation with carbon storage or carbon sequestration. Similar to the search for ways to conserve water, many parts of the United States are looking for effective ways to sequester the carbon dioxide gases that contribute to global climate change. Several studies have estimated the potential of various regions of the United States to convert and store terrestrial carbon (i.e., store carbon in plant matter).Much of the research focuses on carbon sequestration potential of various land use activities including rangeland and cropland afforestation, changes in riparian buffer management, and hazardous fuel reduction to reduce emissions each activity and include economic analysis to address the total costs of converting lands or changing management to sequester carbon. For example, Oregon's land use planning program has protected an estimated 1.2 million acres of forest and agricultural land from development since 1973 and avoided an equivalent 1.7 million metric tons of carbon dioxide emissions annually—the amount of carbon that would have been emitted by 395,000 cars in a year (PNRS 2009).

4. Conservation and Restoration Resource Target Scenarios

The five individual resource function layers (groundwater quality, groundwater quantity, surface water quality, surface water quantity, and habitat) were merged to generate a conservation and restoration resource target map that identifies areas for restoration or conservation, based on a comparison of historic and existing conditions (e.g., historic and existing water storage) or presence/absence of historical attributes (e.g., permeable land surface).The five resource layers were, metaphorically speaking, “stacked” together, and the data in each of the five layers were averaged for each pixel location across all five resource layers (refer back to Figure 2) to produce a single map. Conservation and restoration resource targets have been developed at a scale appropriate to the available data. Because the land use regulatory system operates at different political and legal scales than the natural scales of ecosystems (Arnold 2007), individual projects developed as part of future efforts will have to be examined at the appropriate scale.

A GIS button tool was developed to automate scenario development of the resource target map (outlined previously in Figure 1).Using the tool, different scenarios are developed by assigning different weights to resource function layers (Figure 11).A scenario would be based on the relative importance of each resource function layer and footprint of the proposed project and the current or future land use, i.e. the user could look at the total impact of a proposed project on the five resource layers combined and/or one or more layers at a time. If the surface water quality and quantity functions were considered adequate for a particular purpose, such as evaluating potential NPDES permitting, the other layers could be omitted. Three examples are presented here below.

Example 1. A resource target map in which all resource function layers are weighted with equal importance (Scenario 1) has each layer assigned the same weight (i.e. all ones or all twos; Figures 12 and 13). The restoration targets in Scenario 1 occur predominantly in the highly urbanized area of the Winter Haven Ridge and the City of Winter Haven. This area is characterized by a dramatic loss of habitat, poor water quality, and reduced groundwater infiltration due to development. The “green” conservation targets are associated with existing freshwater marshes that still offer valuable habitat function and surface water storage. Most of the remaining area is identified as restoration (tan colored) and appears to correspond predominantly with existing agricultural areas that also provide surface water storage, albeit not as much as the “green” targets.

Example 2. An alternate scenario, Scenario 2, can be generated if more importance to the surface water quantity resource function layer is preferred when compared to the other resource function layers. Assigning the surface water quantity layer a weight of “3” results in a scenario in which surface water quantity has three times more influence than the other four resource function layers (Figures 14 and 15). Similar to Scenario 1, the restoration targets are predominantly in the heavily developed City of Winter Haven. However, weighting the surface water quantity resource function more than the other resource layers shifts the map to include many more of the green conservation areas(e.g. in the northern portion of the watershed).

Example 3.A water storage scenario, Scenario 3, was generated to assign greater importance to the surface and ground water quantity resource function layers when compared to the other resource function layers. Assigning the surface water and groundwater quantity layers a weight of “1” and other layers as zero results in a resource target scenario in which water quantity has the only influence (Figure 16 and 17).

Additional resource target scenarios are presented in Appendix C, in which the effects of assigning a weight of “3” to one individual resource function layer (Scenarios 3 to 6) are displayed. In addition to assigning weighted importance to resource function layers, layers can be eliminated from the resource target map by assigned a value of “0.” Scenario development is intended to allow the user to evaluate the potential impacts of projects on various resource functions or combinations of functions.

Figure 11. GIS button tool developed to assign weights and automate scenario development.

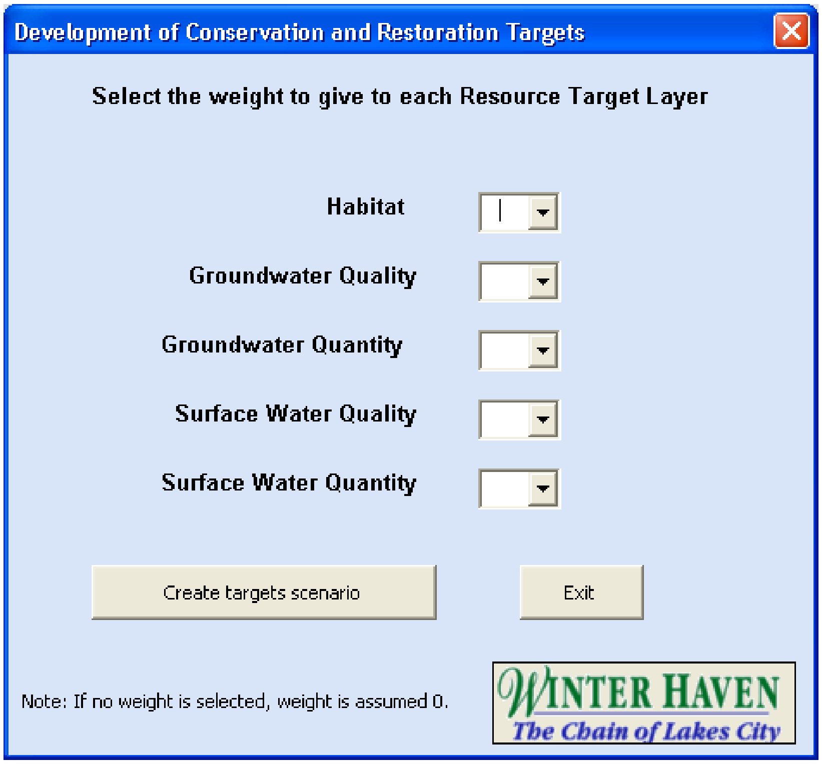


Figure 12. Scenario 1: example of GIS button tool when all resource function layers are assigned equal weights

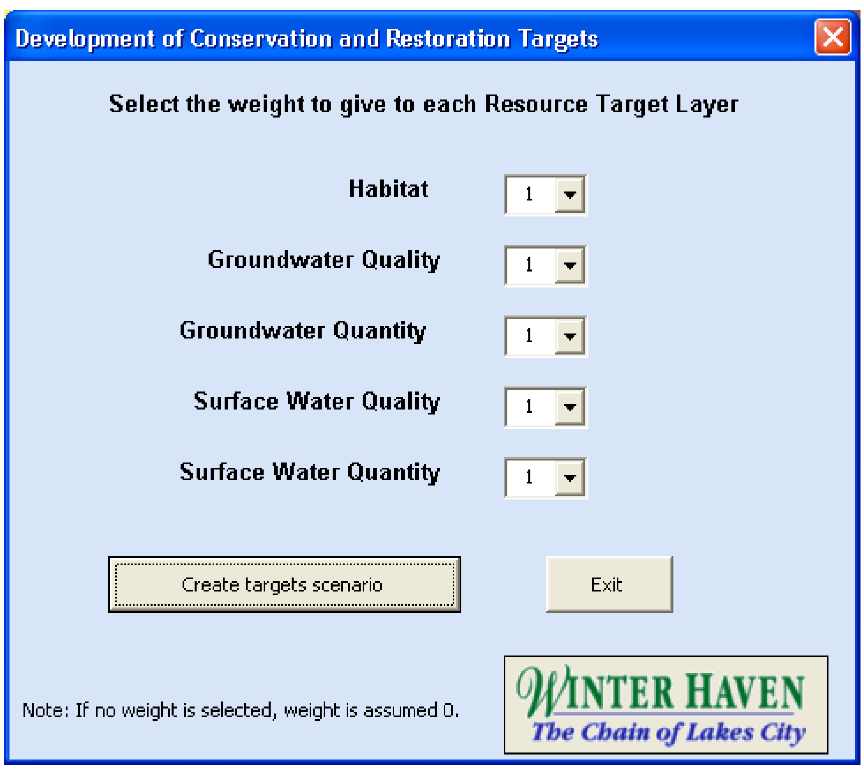


Figure 13. Scenario 1: conservation and restoration resource target map when all resource function layers are assigned equal weights.

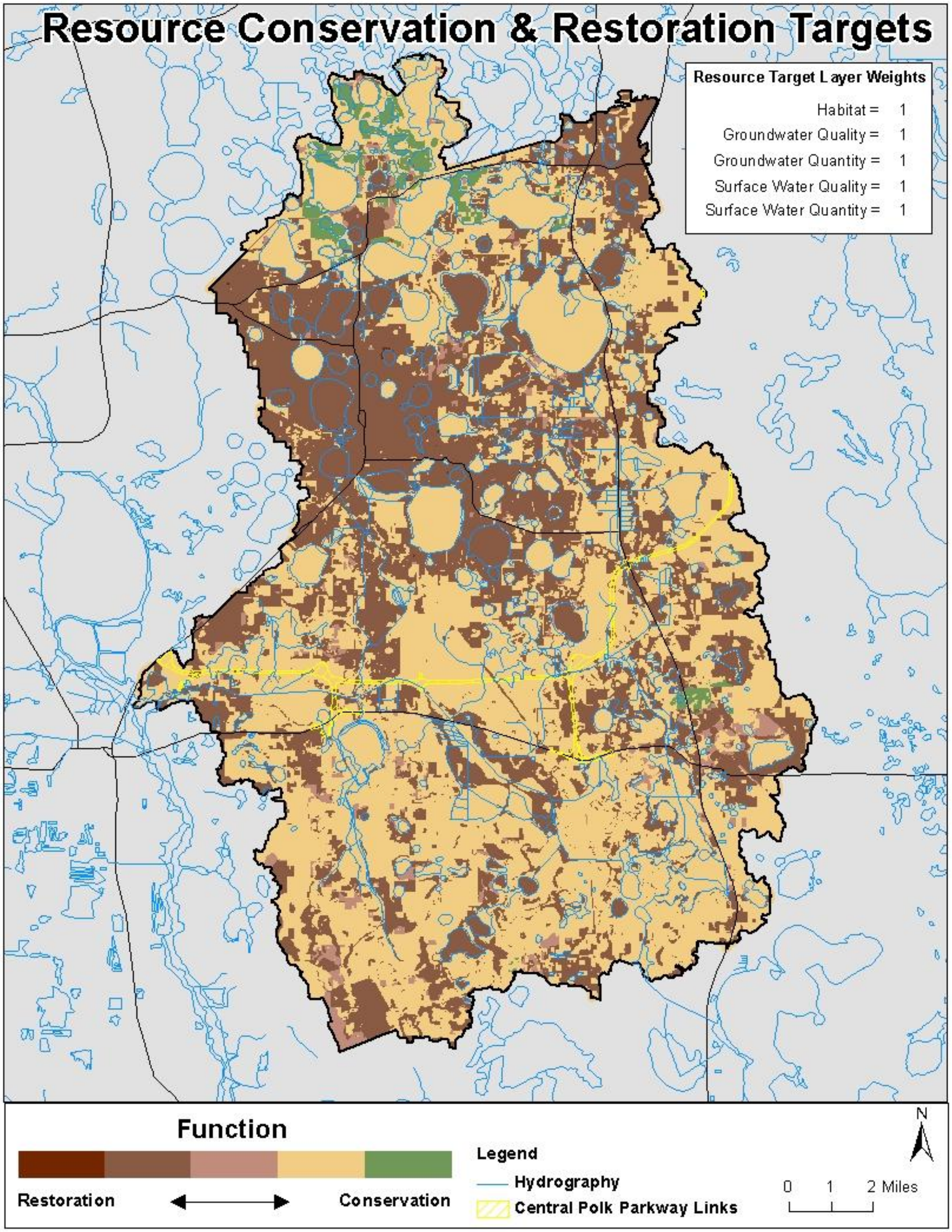


Figure 14. Scenario 2: example of GIS button tool when surface water quantity is assigned a weight of "3" with all remaining resource function layers are assigned equal weights of"1."

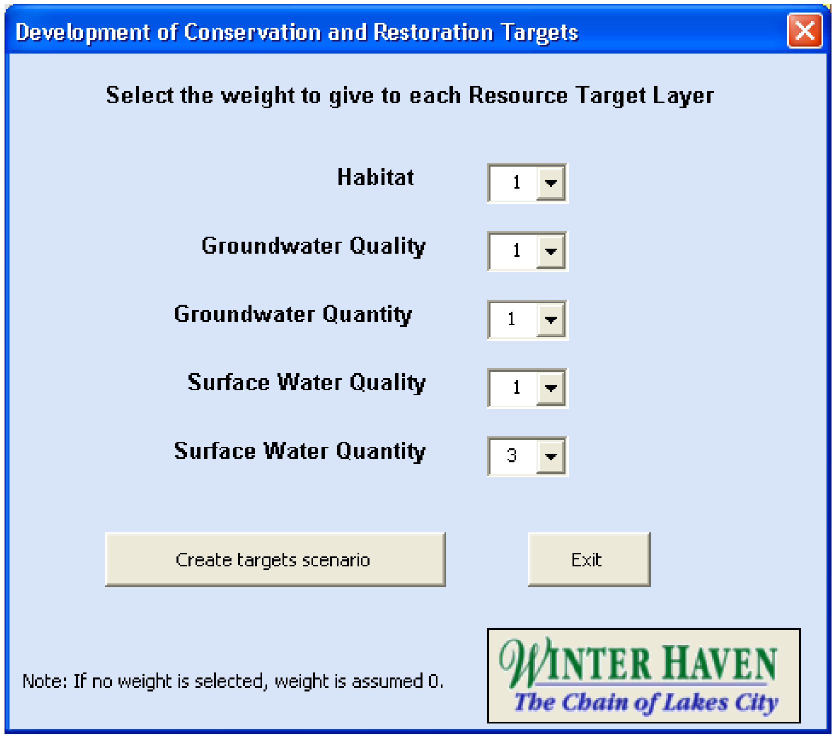


Figure 15. Scenario 3: example of GIS button tool when surface water quantity and groundwater quantity are assigned a weight of "1" with all remaining resource function layers are assigned equal weights of "0."

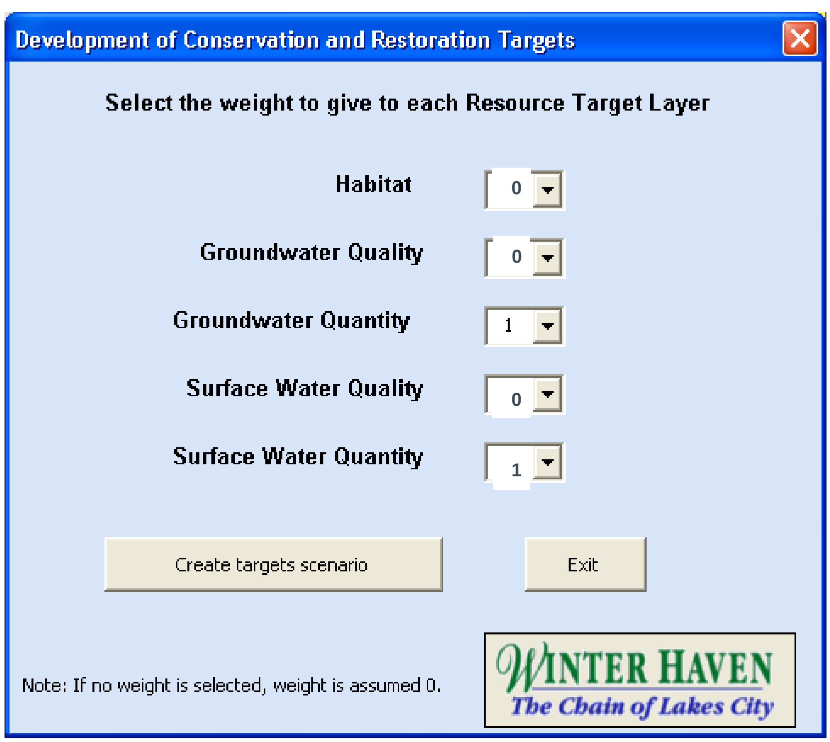


Figure 16. Scenario 2: conservation and restoration resource target map when surface water quantity is assigned a weight of "3" with all remaining resource function layers are assigned equal weights of"1."

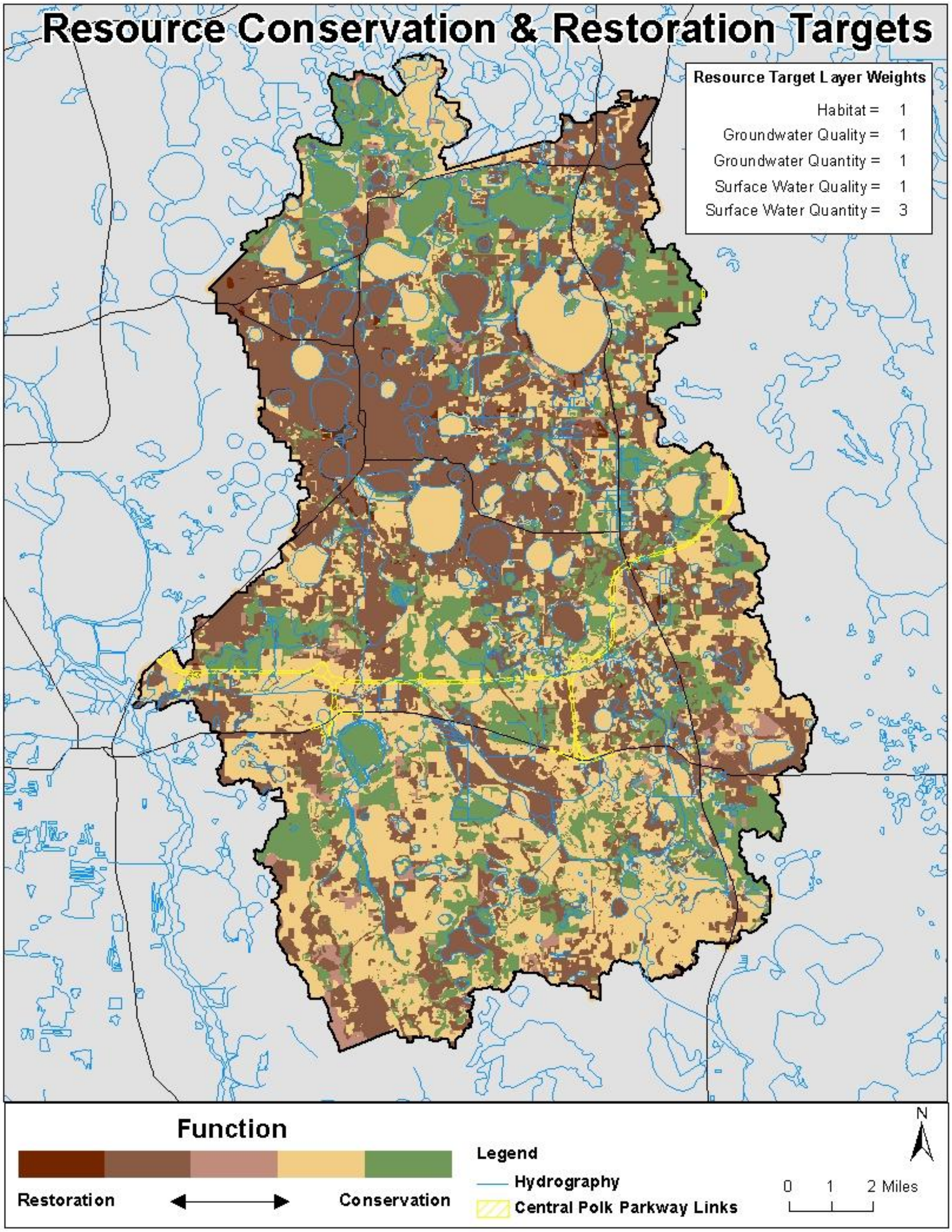
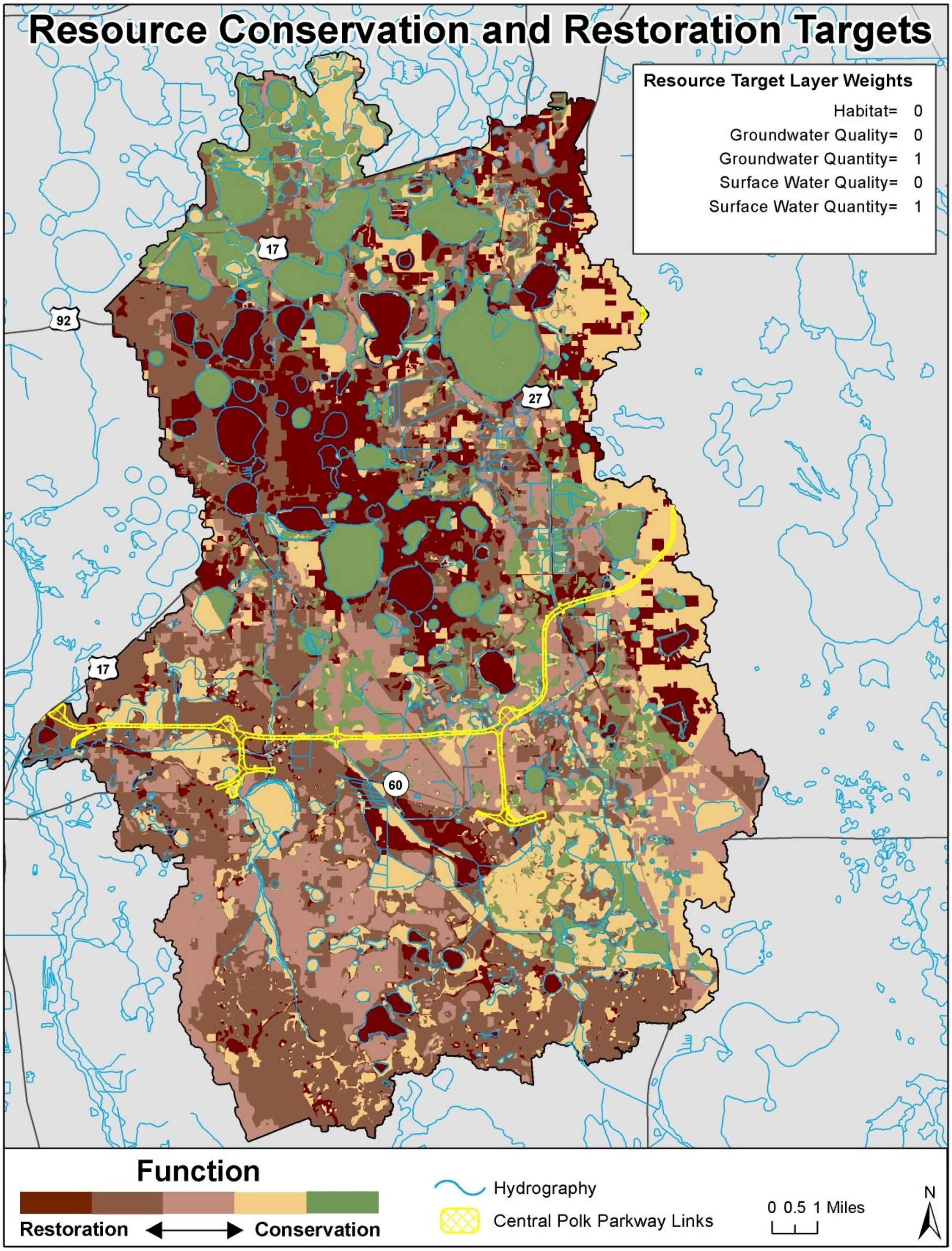


Figure 17. Scenario 3: conservation and restoration resource target map when surface water quantity and groundwater quantity are assigned a weight of "1" with all remaining resource function layers are assigned equal weights of "0."



5. Resource Target Verification

Several of the data sources provided worthwhile information with respect to specific components of the resource function layers, although some sources were not appropriate for inclusion in resource target development due to limited spatial coverage. These data layers may characterize or provide information about portions of the watershed, but do not provide a means of interpreting change or impact and were not considered appropriate for targeting resources. For example, water use permit data are site specific and do not provide a measure of any sort of trend, although the information is especially valuable once a particular site of interest is identified. Elevations are another example—a low elevation does not indicate a wetland unless it is surrounded by higher elevations, so elevation alone is not a good measure of potential water storage. A physiographic divisions such as the Lake Wales Ridge is characterized by high-groundwater recharge, but does not impose a certain amount of groundwater recharge on a location. Examples of data layers precluded from resource target analysis are listed below.

Limited spatial coverage (i.e., site specific without applicability over study area). For example:

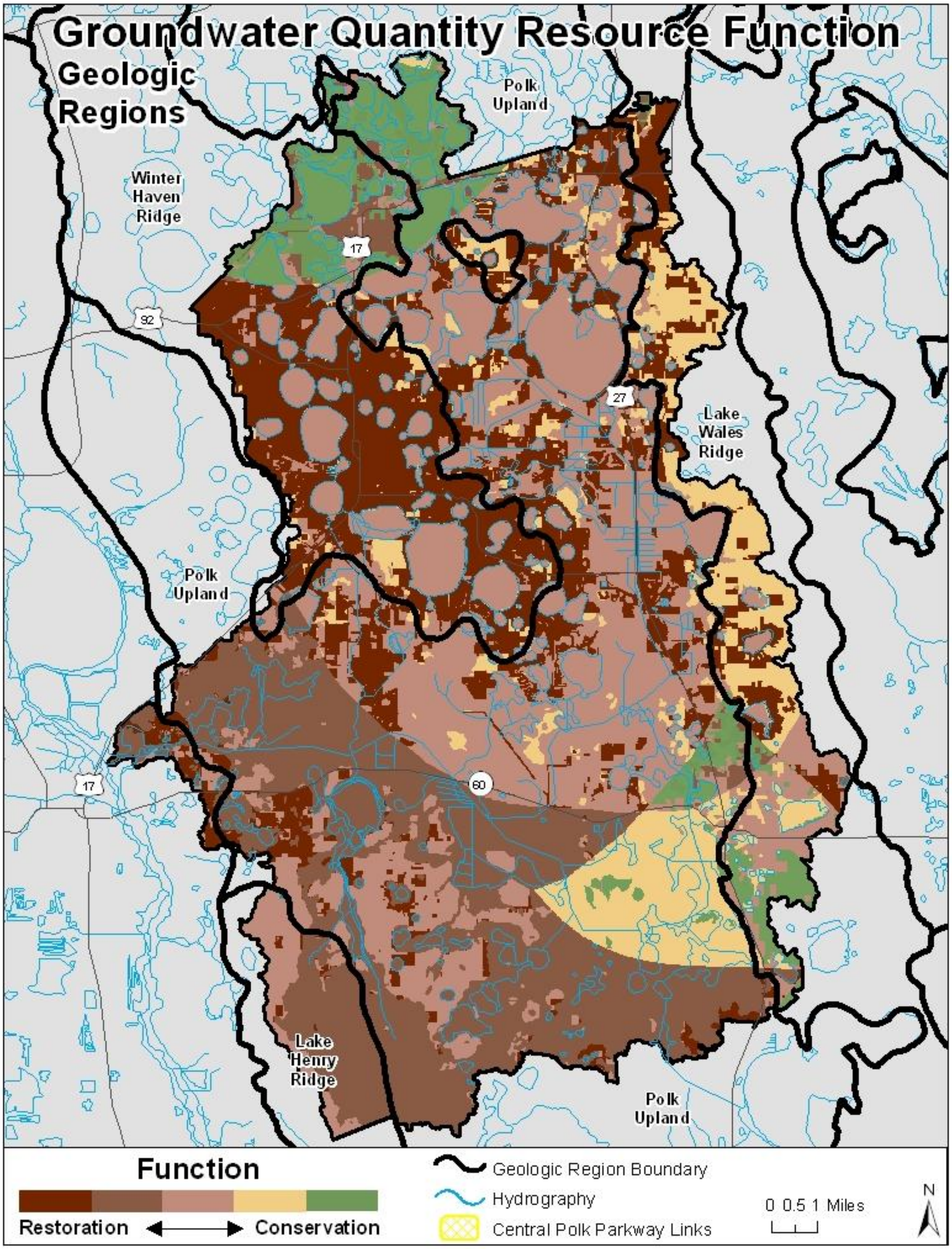
- Water use permits
- Brownfield sites
- Sinkholes
- Wells and wellfields

General characterization not susceptible to restoration or conservation. For example:

- Transmissivity
- Physiographic divisions
- Topography
- Hydrography

These data sources were not used for the development of the resource function layers but will be useful (and necessary) for resource target verification and potential site exclusion. Superimposing these data layers over the conservation and restoration resource target maps allows the user to verify attributes of interest—the Lake Wales ridge corresponds to high-recharge areas and topographic changes correspond to waterways and lakes. For example, the physiographic division data were used to validate the groundwater quantity resource function (Figure 18).The groundwater quantity resource function map adequately portrays the Winter Haven Ridge, which historically provided significant groundwater recharge and is identified for “restoration” due to the significant urban development (Figure 18).Brownfield site data may be used to provide supplemental information after potential areas for restoration/conservation have been selected.

Figure 18. Verification of groundwater quantity resource function layer using the physiographic division data.



6. Conclusions: Water Resource Targets

Conservation and restoration resource targets were developed for this project in support of the City of Winter Haven's recently developed *Peace Creek Sustainable Water Resource Management Plan*. Resource targets were developed so that resource benefits (services)such as water supply and water quality can be restored and/or conserved and continue to provide benefits or ecosystem services that cost virtually nothing, but are critical to the support of a growing human economy. The conservation and restoration targets developed and presented here provide a template for evaluating existing land uses and including institutional measures in future development to protect ecosystem benefits.

Data relevant to each of the targets of interest were incorporated into a GIS platform to support future decisions related to land use and restoration/conservation projects. Local governments face substantial obstacles to using land use regulatory powers to protect ecosystems (Arnold 2007), however, the City of Winter Haven has elected to pursue institutional solutions instead of solely technology-based structural solutions in support of its sustainable water management plan and institutional sustainability over technological sustainability, as outlined in Figure 19 (modified from Katsiardi et al. 2005). To the extent that the restoration and conservation of priority locations cannot be accomplished through land planning and other non-structural controls, engineering and other structural controls will need to be identified to meet the targets. Since these controls are less effective and more costly to implement than non-structural controls, the City should leverage its land planning authorities, including the use of incentives to protect water resources, to the greatest extent possible. The City may also implement monitoring and other feedback mechanisms for adaptive management.

Figure 19. Components of sustainability planning: a gradient of sustainability.

Technical/structural solutions	Technical sustainability	Balanced demand and supply
	Financial sustainability	Least-cost solutions
	Environmental sustainability	No long-term negative or irreversible effects
	Economic sustainability	Economic development and welfare of society
	Social sustainability	Stability of demand, willingness to pay
Institutional/non-structural solutions	Institutional sustainability	Capacity to plan, manage, and operate the system

Data were integrated into the GIS platform to develop relationships between water resource functions, including groundwater quantity, groundwater quality, surface water quantity, surface water quality, and habitat, and corresponding community benefits (i.e., fish and wildlife habitat) drinking water supply, clean groundwater, surface water storage, flood protection, and recreation and cultural benefits (swimmable/drinkable/fishable surface water), respectively. Comparisons between historic (circa 1940s) or unimpacted/undeveloped and present conditions were made to identify conservation (little change from historic conditions) and restoration (greater change from historic conditions) targets that should be included as part of future land use planning. Water quality comparisons were based on regulatory definitions (impaired water quality).

The surface water and groundwater quantity resource function layers were the most comprehensive of the five resource function layers with respect to the amount of data and areal extent of data available. Surface and groundwater are also of particular interest at both state and local levels, as described in the sustainability plan. Consequently, these data layers were mapped as water resource data layers (Figure 20). To further focus on restoration and conservation targets with higher priority, the 30th percentile for groundwater target areas and 100 percent of the potential surface water storage were retained for displaying water resource data layers and targets. In addition, “noise” was removed from the final map by removing contiguous areas greater than 20 acres in size. However, 100 percent of the target areas are retained in the project GIS layers to provide additional data as appropriate. In some cases, discrepancies were noted in the water resource data map/model.

Examination of several of these occurrences indicates that existing land use data may provide historic wetland signatures that are no longer wet due to the persistence of wetland vegetation. For example, land use/land cover data result in a designation of most of Lake Lulu as restoration, while along the southern shore, the lake is designated conservation. The conservation designation is a result of the persistence of the wetland forest species in that area, i.e., although the water levels are lower, the trees remain, and the signature “tricks” the GIS into designating the remaining wetland trees as a wetland forest and, therefore, a conservation area. Similarly, much of the Mann-owned property at the U.S. 27 and S.R. 540 is identified as wet prairie because it does, in fact, have the aerial photograph “signature” of wet prairie, in spite of ditching and draining activities. Therefore, the shift in land cover is not conspicuous and the change is storage is not identified. To address known issues, project specific data/studies were used to alter data layers.

A second map, or model, of the water resource targets areas (Figure 21) was subsequently prepared to reflect locally-specific data in addition to watershed-scale data layers – this is the water resource management target areas mapped in Figure 21. In this way, potential storage areas misidentified based on land cover were included as restoration targets (rather than conservation). Data layers included the Sapphire Necklace developed as part of the Peace Creek Sustainable Water Management Plan (City of Winter Haven 2011), as well as lakes designated as “stressed” by the SWFWMD, and lakes with established minimum levels.

Project impacts

The most obvious utility to the conservation and resource targets is as a mechanism for evaluating impacts of proposed or existing projects, siting conceptual projects, and identifying opportunities for trade-offs between development and ecosystem benefits. Changing scenarios allows the user to examine the impacts of proposed projects using one or any combination of resource function layers to identify resources that may be affected or can be more easily avoided. Impacts of the Central Polk Parkway appear to be related to surface water quantity, with very little relative impact to surface water quality, groundwater quality and quantity, and habitat. Directing mitigation to address loss of surface water storage conservation may be a higher priority than other resource functions in this particular case.

The conservation and restoration targets are also a mechanism by which to quantify the loss of services and mitigate for that loss. If groundwater quantity impacts are identified, opportunities to mitigate for the impacts elsewhere in the watershed can be readily identified. The resource targets therefore provide a context for developing land use measures to guide revisions to the City’s land use ordinances and development regulations and to develop incentives for protecting water resources. The goal of the incentives will be to reward landowners for protecting landscape features that contribute to or provide water resource benefits. The end result of this effort will be to revise the City’s ordinances and develop incentives, which will be addressed in a subsequent scope of work.

Figure 20. Composite water resource data layers for the Peace Creek Watershed.

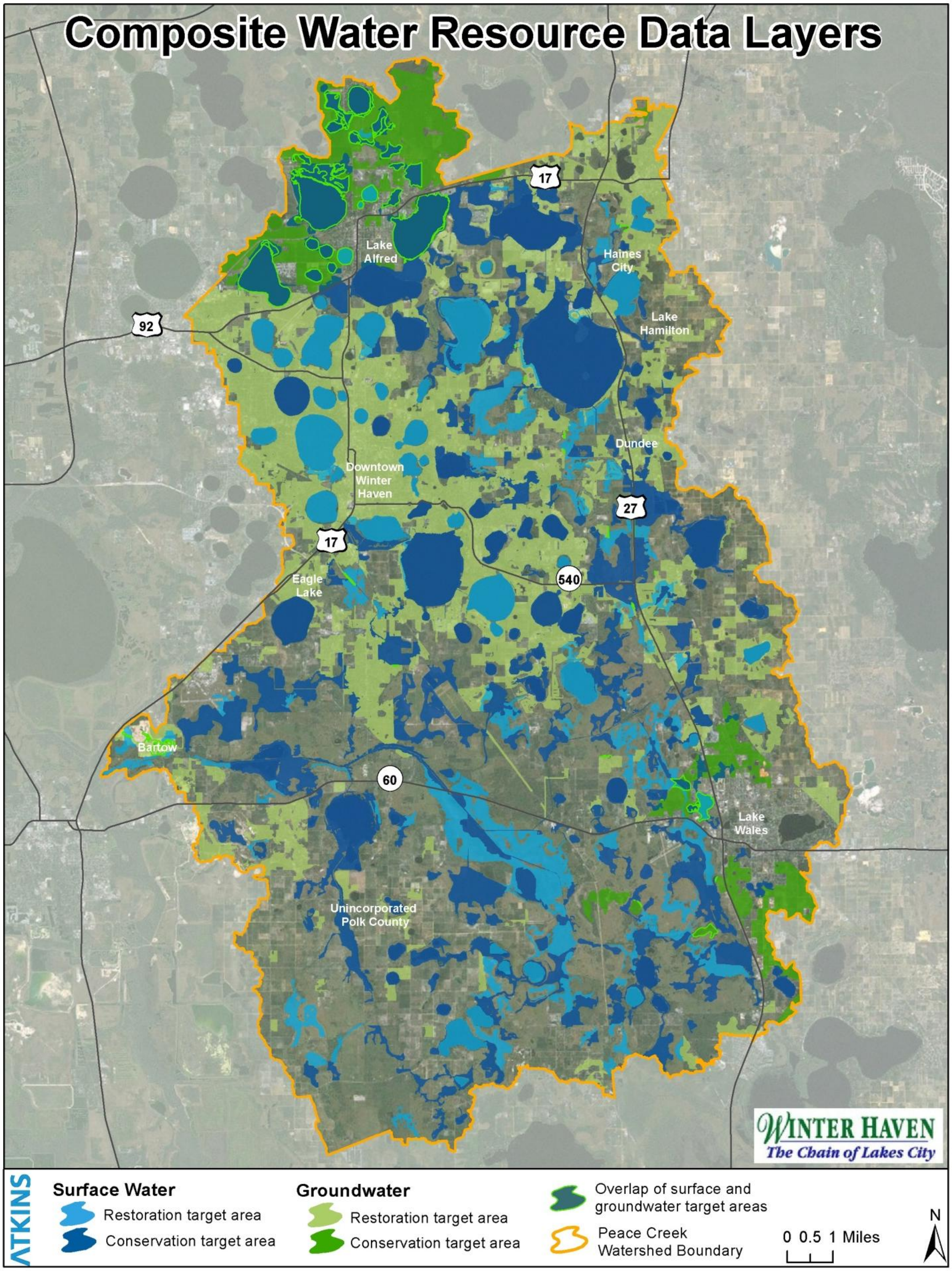
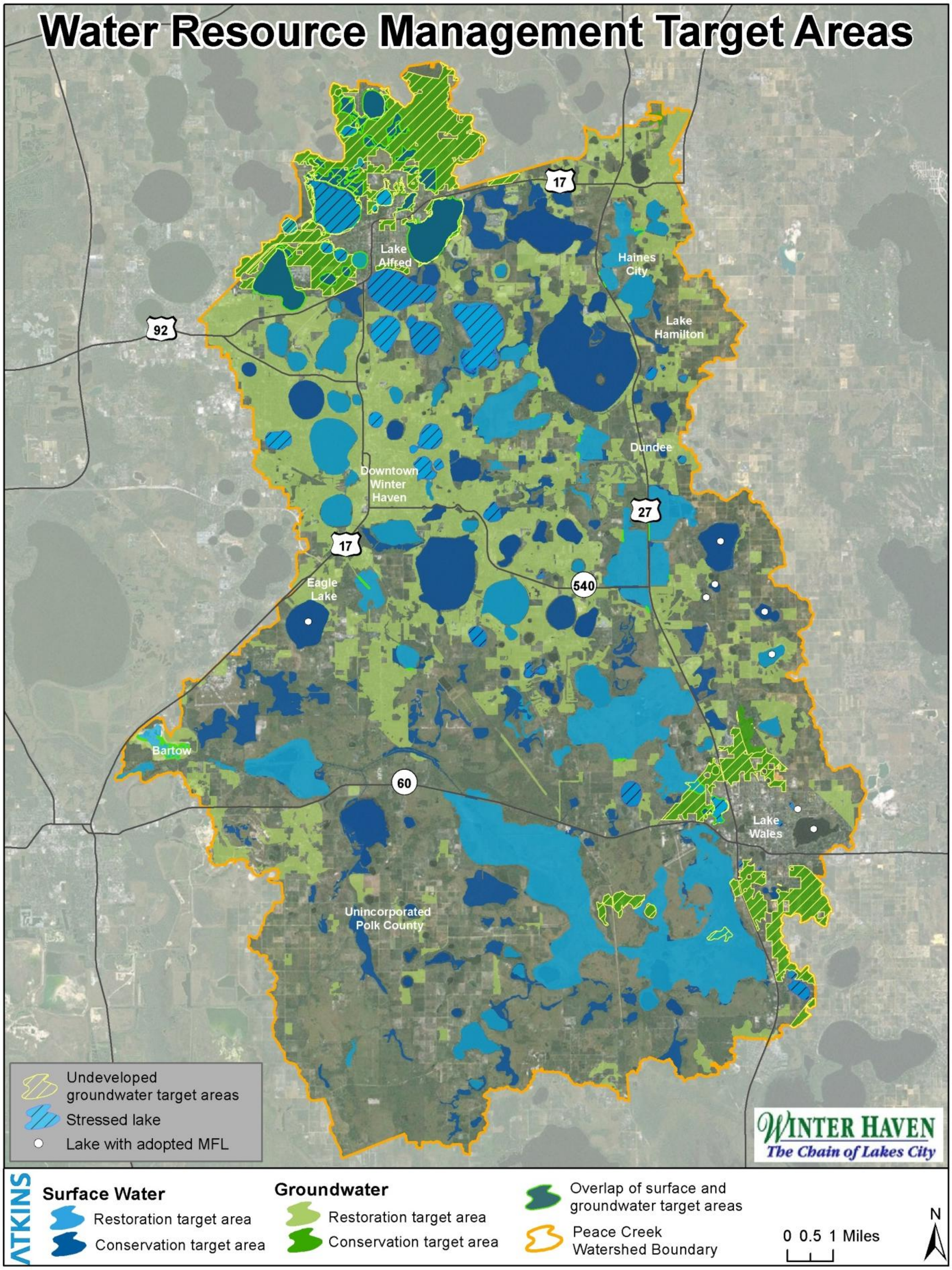


Figure 21. Water resource management target areas for the Peace Creek Watershed.



Future planning

Evaluating impacts is the most straightforward use of restoration targets. Identification of areas for future restoration and conservation is even more important from a planning perspective. Local governments cannot always choose the areas available for conservation or restoration and properties designated as restoration or conservation targets have been designated as such based on available data. However, knowing what a property may provide in terms of ecosystem function and/or benefit can allow local government to leverage it for another property or benefit trade. All planning efforts should include the resource targets as a guide for future acquisitions and development. Supplemental planning information, including the Sapphire Necklace outlined in the City's *Sustainable Watershed Management Plan,* lakes with adopted MFLs, and stressed lakes, have been superimposed over the restoration and conservation targets. The resource targets model further substantiates that the Sapphire Necklace are consistent with surface water restoration and conservation targets in the southern portion of the watershed.

Quantifying the resource targets allows the implementation of strategies to examine specific projects, options for land use planning, and private-sector concepts such as mitigation banking and regional stormwater ponds. For example, Roanoke, Virginia, has set a goal of reaching a 40percent tree canopy, increased its tree planting budget, modified its land use regulations to require more trees and their protection for new development, and partnered with other agencies, land trusts, and the public to plant more trees, in recognition of the facts that trees filter air pollutants, absorb runoff, and reduce air temperatures. New York City exercised extraterritorial regulatory jurisdiction over land use in upstate areas to prevent development that would pollute drinking water sources via surface water runoff and groundwater recharge. The City acted because the costs associated with land use regulation and land acquisition were less than the costs of building additional water treatment facilities (Thompson 2000).

The targets for restoration and conservation in the watershed are based on available watershed-level data. Once these targets become part of the planning process, specific restoration and conservation projects can be located appropriately throughout the watershed, while development can be directed in a way that is consistent with the restoration and conservation targets. These land use mechanisms can include revisions of existing ordinances, development incentives, or other mechanisms that will be developed as part of the next step in carrying out the City's *Sustainable Water Resource Management Plan*.

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Appendix A. Available Data for Development of Restoration and Conservation Targets

Class	File Name	Shapefile Name	Description	Suggested Approach	Proposed Buffer (feet)	Comments	Data Source
Contamination	Biomedical Waste Facilities	biomed_waste_oct10.shp	Shows the location of biomedical waste facilities inspected by the Department of Health.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FGDL
Contamination	Brownfield Areas	brownfields.shp	Shows areas of contiguous brownfield sites which are abandoned, idled, or underused industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived contamination.	Buffer and avoid.	500	These sites should be avoided. (there are only two within the study area.)	FGDL
Contamination	Closed Hazardous Waste Facilities	closed_haz_waste_facilities.shp	Shows the location of facilities that are closed but were regulated by the RCRA.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FDEP
Contamination	EPA National Pollutant Discharge Elimination System	epanpdes_may11.shp	Shows the location of facilities that discharge to water and information on the permits from the EPA.	May not be useful for our purposes.	NA	There are many sites within the study area.	EPA
Contamination	EPA Regulated Superfund/NPL Sites	epasuperfund_may11.shp	Shows the location of known releases or threatened releases of hazardous substances.	Buffer and avoid.	500	There is one site within the study area that may be of concern.	EPA
Contamination	EPA Storage and Retrieval System For Water Quality Monitoring	epa_storet.shp	Shows the location of water quality monitoring sites that are within the EPA's STORET system.	Surface water quality locations. May be useful in hydrogeologic characterization.	NA	There are many sites located within the study area. Water quality data may be available.	FGDL
Contamination	EPA Toxic Release Inventory	epatri_2009.shp	Shows the location of facilities that release toxic chemicals	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	EPA
Contamination	FDEP Dry Cleaning Program Sites	dryclean_pub_apr11.shp	Shows the location of contaminated dry cleaning sites	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FDEP
Contamination	Groundwater Contamination Areas	groundwater_contamination.shp	Shows the location of areas delineated for groundwater contamination.	Avoid (appear to be buffered points).	0	There are many sites within the study area that may be of concern.	FDEP
Contamination	Impaired Water Bodies	impaired_water_bodies.shp	Shows impaired waters that do not meet water quality standards	Buffer and avoid.	200	These bodies of water should be avoided. We are reviewing appropriate buffers. Tentatively considering 200 feet for all Class 3 lakes (including impaired water bodies) and 50 feet for all wetlands.	FGDL
Contamination	Large Quantity Generators of Hazardous Waste	lqgs_pub_apr11.shp	Shows the location of generators of 1,000 kg or more of hazardous waste in any one calendar month.	Buffer and avoid.	500	There are several sites within the study are that may be of concern.	FDEP
Contamination	Limited Use Drinking Water Wells	drinkwater_oct10.shp	Shows the location of limited use public water systems inspected by the Department of Health.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FGDL
Contamination	Onsite Sewage Locations	septic_oct10.shp	Shows the location of onsite sewage treatment and disposal systems inspected by the Department of Health.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FGDL
Contamination	Petroleum Contamination Monitoring Sites	pcts_pub_apr11.shp	Shows petroleum contamination tracking sites.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FDEP
Contamination	RCRA Regulated Facilities	eparcra_may11.shp	Shows sites regulated by RCRA that handle hazardous waste.	Buffer and avoid.	500	There are many sites within the study area that may be of concern. File provided by the EPA and appears to list many more sites than the DEP file.	EPA
Contamination	Reported Petroleum Contamination	reported_petro_discharge.shp	Shows the location of facilities that have had at least one reported petroleum discharge.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FDEP
Contamination	Small Quantity Generators of Hazardous Waste	sm_quantity_haz_waste_gen.shp	Shows the location of generators of greater than 100 kg but less than 1,000 kg of hazardous waste in any one calendar month.	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FDEP
Contamination	Solid Waste Facilities	solid_waste_facilities.shp	Shows solid waste facilities	Buffer and avoid.	500	These sites are monitored for their potential impact to groundwater and should be avoided.	FDEP
Contamination	Source Water Assessment and Protection Program Areas	swapp_jun08.shp	Shows potential contamination sources (PCS) to the ground water used by Public Water System (PWS) wells.	May be useful in analysis.	500 - 1000	PWS wells are divided into three categories: 1) noncommunity, 2) community serving populations less than 1,000 persons and 3) community serving populations greater than or equal to 1,000 persons. Assessment areas for noncommunity wells are a 500 ft radius buffer of the well. Assessment areas for community wells serving populations < 1,000 persons are a 1,000 foot radius buffer of the well. Assessment areas for community wells serving populations >= 1,000 persons are a 1,000 foot radius buffer of the well plus a five year ground water travel time.	FDEP
Contamination	State Funded Hazardous Waste Cleanup Sites	state_cleanup_sites.shp	Shows the location of FDEP State Funded Hazardous Waste Cleanup Sites (proposed, active, or delisted)	Buffer and avoid.	500	There are two sites within the study area buffer, only one is within the study area in the northwest corner that may be of concern.	FDEP
Contamination	Storage Tank Contamination Monitoring	stcm_pub_apr11.shp	Shows the location of all registered petroleum facilities.	Buffer and avoid.	500	There are many sites within the study area that may be of concern. There appear to be similar sites listed in the file pcts_pub_apr11.shp.	FDEP
Contamination	Super Act Risk Sources	superact_risk_apr11.shp	Shows the location of petroleum and drycleaning facilities.	Buffer and avoid.	500	There are many sites within the study area that may be of concern. The files appears to have similar sites listed in the pcts_pub_apr11.shp and dryclean_pub_apr11.shp.	FGDL
Contamination	Treaters, Storers, and Disposers of Hazardous Waste	tsds_pub_apr11.shp	Shows the location of sites regulated by RCRA that handle hazardous waste.	Buffer and avoid.	500	There are two sites within the study area buffer; only one site is actually within the study area. File provided by the DEP and appears to list a significantly less amount of sites than the EPA file.	FDEP

Class	File Name	Shapefile Name	Description	Suggested Approach	Proposed Buffer (feet)	Comments	Data Source
Contamination	Underground Injection Control Class 5 ASR Wells	uic_class5_asr_sp_vw.shp	Shows the location of all Class 5 Aquifer Storage and Recovery (ASR) Underground Injection Control (UIC) wells that are currently or previously active.	NA	NA	There are no sites within the study area.	FGDL
Contamination	Underground Injection Control Class 5 Non-ASR Wells	uic_class5_nonasr_sp_vw.shp	Shows the location of all Class 5 Non-Aquifer Storage and Recovery (ASR) Underground Injection Control (UIC) wells that are currently or previously active.	Potentially buffer and avoid depending on depth.	500	There are two sites within the study area buffer, only one is within the study area. Class V wells generally inject nonhazardous fluid into or above an underground source of drinking water (USDW), defined as an aquifer that contains a total dissolved solids concentration of less than 10,000 milligrams per liter.	FGDL
Contamination	Underground Injection Control Class I Wells	uic_class1_sp_vw.shp	Shows the location of all Class I Underground Injection Control (UIC) wells that are currently or previously active.	NA	NA	There are no sites within the study area.	FGDL
Contamination	Water Supply Restoration Wells	wsrp_private_wells.shp	Shows the location of FDEP Water Supply Restoration Program private drinking water well contamination	Buffer and avoid.	500	There are many sites within the study area that may be of concern.	FGDL
Hydrogeology	Aquifer Performance Test for Intermediate Aquifer System	apt_intermediate_aquifer.shp	Shows the location of wells used in the APT of the IAS	May be useful in hydrogeologic characterization.	NA	There are three sites within the study area buffer, one is within the study area. The test results can be found in the "Aquifer Characteristics Within the SWFWMD" report.	FGDL
Hydrogeology	Aquifer Performance Test for Surficial Aquifer System	apt_surficial_aquifer.shp	Shows the location of wells used in the APT of the SAS	May be useful in hydrogeologic characterization.	NA	There are two sites within the study area buffer, one is on the very northern edge of the study area. The test results can be found in the "Aquifer Characteristics Within the SWFWMD" report.	FGDL
Hydrogeology	Aquifer Performance Test for Upper Floridan	apt_upperfloridan_aquifer.shp	Shows the location of wells used in the APT of the Upper FAS	May be useful in hydrogeologic characterization.	NA	There are two sites within the study area buffer, one is within the study area. The test results can be found in the "Aquifer Characteristics Within the SWFWMD" report.	FGDL
Hydrogeology	Closed Topographic Depressions	ctds.shp	Areas of very limited or no drainage	Calculate distance surface and use as factor in site selection. Closer is better. But inside is not allowed.	Continuous distance	There are numerous closed topographic depressions in study area and are sinkholes in many cases. May want to use distance from CTDS as a factor in RIB siting. While this was just one factor in FAVA, we may want to make it a higher priority or use as secondary screening.	FGDL
Hydrogeology	Floridan Aquifer System Response	fas_response	Shows the vulnerability of the FAS to contamination	Recommend not using directly, but weighting components as appropriate for study area.	NA	This file shows the whole study area as highly vulnerable to FAS contamination relative to areas just to the south. Within study area there is relatively little differentiation from the model. I recommend weighting certain factors differently, since we know the importance of the soil permeability, soil drainage class, and proximity of karst features.	FGS
Hydrogeology	Geologic Units and Structural Features in Florida	geology_stratigraphy.shp	Shows the geological units, age, and rock type.	May be useful in hydrogeologic characterization.	NA	The study area contains two age groups: Pliocene and Miocene. In addition to different rock types: sand and clay or mud.	FGDL
Hydrogeology	Head Difference	head_diff	Shows the hydraulic head difference between the SAS and the FAS by subtracting the FAS potentiometric surface from the SAS water table surface.	Establish cut-off, if any, for exclusion of discharge areas and possibly those with very high head differences (if any).	NA	There is little variation across study area. Most of the study area is between -10 and +10 head difference. Areas in the southwest may be less suitable as they have a larger head difference of > 10 feet, possibly reflecting some confinement. (Note that for the FAVA head difference was based on pre-development conditions.)	FGS
Hydrogeology	Hydrostratigraphic Top of the Floridan Aquifer System	fas_top	Shows the hydrostratigraphic surface of the FAS	May be useful for characterizing hydrogeology of area.	None		FGS
Hydrogeology	Hydrostratigraphic Top of the Intermediate Aquifer System	ias_top	Shows the hydrostratigraphic surface of the IAS	May be useful for characterizing hydrogeology of area.	None		FGS
Hydrogeology	Intermediate Aquifer System Response	ias_response	Shows the vulnerability of the IAS to contamination	Not recommended for use in our analysis.	NA	Most of the study area is classified as "More Vulnerable". Northern portion of study area shows no data possibly due to no known SAS or lack of well data	FGS
Hydrogeology	Intermediate Aquifer System Thickness	ias_thk	Shows the thickness of the IAS	Establish threshold or use as quantitative factor.	NA	In the figure, it appears that the central to north central portion of study area is more suitable due to thinner IAS/ICU. This IAS map follows the FGS IAS map fairly closely with some differences.	FGS
Hydrogeology	Intermediate Aquifer System Thickness (FGS)	ias_thk_smth	Shows the thickness of the IAS	Use FAVA data instead.	NA	This file is similar to the IAS thickness file obtained through FAVA.	FGS
Hydrogeology	Physiographic Divisions of Florida	physiographic_divisions.shp	Shows the locations and names of physiographic units.	May be useful in hydrogeologic characterization.	NA	The majority of the study area is "Winter Haven Karst".	FGDL
Hydrogeology	Physiographic Regions of Florida	physiographic_regions.shp	Shows the physiographic regions as defined in "The Geomorphology of The Florida Peninsula".	May be useful in hydrogeologic characterization.	NA	The study area contains three regions: Lake Wales Ridge, Winter Haven Ridge, and Polk Upland.	FGDL
Hydrogeology	Potentiometric Surface Map for the Floridan Aquifer System (May)	may08fl_line.shp	Shows the potentiometric surface for the FAS during May	May be useful in analysis.	NA		SWFWMD

Class	File Name	Shapefile Name	Description	Suggested Approach	Proposed Buffer (feet)	Comments	Data Source
Hydrogeology	Potentiometric Surface Map for the Floridan Aquifer System (September)	sept08fl_line.shp	Shows the potentiometric surface for the FAS during September	May be useful in analysis.	NA		SWFWMD
Hydrogeology	Pre-development POT for the Floridan Aquifer System	predevfl_line.shp	No metadata available	May be useful in analysis. Incorporated into the Head Difference file already.	NA		SWFWMD
Hydrogeology	Pre-development POT for the Intermediate Aquifer System	predevint_line.shp	No metadata available	May be useful in analysis.	NA		SWFWMD
Hydrogeology	Recharge/Discharge of the Floridan Aquifer System	floridanrecharge.shp	Generalized recharge to and discharge from the Floridan Aquifer System.	May be useful in hydrogeologic characterization.	NA	The majority of the study area generally recharges greater than 10. This may be superceded by the Head Difference map from FAVA.	SWFWMD
Hydrogeology	Sensitive Karst Areas in SWFWMD	sensitive_karst_area.shp	Shows the location of formation types determined to be sensitive Karst areas	Unlikely to be useful.	NA	There are no areas identified as sensitive Karst areas within the study area.	FGDL
Hydrogeology	Sinkholes	sinkholes.shp	Reported sinkhole activity; not validated as karst sinkholes by FGS	Calculate distance surface and use as factor in site selection. Closer is better.	Continuous distance	Reported sinkholes could be used in addition to the closed topographic depressions although they may be confined to urban areas.	FGDL
Hydrogeology	Soil Permeability	soil_perm	Shows the soil permeability as a weighted rate (1 to 20 inches/hr)	Establish threshold or use as quantitative factor.	NA	Soil permeability is variable within the study area.	FGS
Hydrogeology	Soils	soils.shp	Shows the soils and corresponding information including drainage	Use soil drainage class to establish suitable and unsuitable areas based on the combined info on drainage and permeability contained in this one attribute.	NA	Focus on areas identified as drained, somewhat excessively drained, well drained, and moderately well drained. These areas tend to have the high permeability soils and occur in higher areas. Therefore both the soils and the FAVA soil permeability should probably be used in the site selection.	FGDL
Hydrogeology	Surficial Aquifer System Depth-to-Water	sas_dtw	Shows the SAS depth-to-water table by subtracting the water table surface from the DEM.	Establish a cut-off depth to SAS water table or use as a quantitative ranking factor.	NA	Appears to be good for showing areas with sufficient space to load the SAS. The cemetery groves site shows about 30 feet depth to water. Part of coverage is missing for northernmost portion of study area so we'll need to determine whether missing part could be calculated but is missing for theoretical reasons (e.g., dispute over existence of SAS) or practical ones (lack of well data).	FGS
Hydrogeology	Surficial Aquifer System Response	sas_response	Shows the vulnerability of the SAS to contamination	Not recommended for use in our analysis.	NA	Most of the study area is classified as "More Vulnerable". Northern portion of study area shows no data possibly due to no known SAS or lack of well data	FGS
Hydrogeology	USGS 1:24,000 Hydrography Lines	hy24l53.shp	Shows hydrological line features from USGS 1:24000 scale DLGs	May be useful in hydrogeologic characterization.	NA	Lists the types of hydrology in the study area (e.g. canal, shoreline).	FGDL
Land Ownership	Parcel	PolkCountyParcel_BufferedStudyArea_AddInfo.shp	Shows parcels and associated information (owner, address, ect.)	Parcel data obtained from Polk County was joined with an additional information table to create a complete record for the entire study area.	None	The parcel data will be used to determine the ownership of desirable RIB locations.	Polk County PA
Land Use	FLUCCFS	LULC09_BufferedStudyArea_Lakes_Wetlands_v1.shp	Shows the wetland and lake land use and land cover	The 2009 FLUCCS data was downloaded in two quads and merged into one shapefile and clipped with the study area buffer and all lakes and wetlands were extracted. May be useful for establishing lake limits for buffering to avoid.	500		SWFWMD
Land Use	Study Area	WinterHavenBoundary_RevisedPostKickOff_PerPB_v2.shp	Shows the agreed upon study area boundary	Used for presentation purposes.	None	This file was created and revised based on a request from the client. (Note: the study area no longer encompasses the entire Winter Haven city limits.)	NA
Land Use	Study Area Buffer	StudyAreaSquareBuffer_v3.shp	Shows an extended square area surrounding the study area	Used for presentation purposes and identifying extent of monitoring well data collection.	None	This file was created to ensure any data outside the immediate study area would be collected and considered for modeling purposes.	NA
Land Use	Winter Haven City Limits	WH_City_Limits.shp	Shows the boundary of the Winter Haven city limits	Used for presentation purposes.	None		FGDL

Class	File Name	Shapefile Name	Description	Suggested Approach	Proposed Buffer (feet)	Comments	Data Source
Monitoring	Groundwater Sites	GroundwaterSites_BufferedStudyArea_v2.shp	Shows the groundwater sites within the study area buffer	The groundwater sites were clipped using the study area buffer to provide a list of potential data collection sites immediately surrounding the study area as well as within it.	None	There were 100 active sites within the study area buffer. A table shows the type of hydrological unit and the count of wells. Data, if available, were downloaded from WMIS, with the exception of Lake Starr. Lake Starr wells are located in the southeast corner of the study area and had no apparent data available through WMIS.	SWFWMD
Monitoring	Water Use Permit Sites	WUPSites_BufferedStudyArea_v2.shp	Shows the water use permit sites within the study area buffer	The WUP sites were clipped using the study area buffer to provide a list of potential potable wells immediately surrounding the study area as well as within it. Buffer and avoid.	500		SWFWMD
Topology	Digital Elevation Model (Grid Format)	dem2009	Shows the elevation surface used in FAVA in with a spatial grain size of 15 meters in ESRI GRID format.	May be used to derive calculations concerning the FAVA.	NA		FGS
Topology	Digital Elevation Model (Imagine Format)	dem2009.rrd	Shows the elevation surface used in FAVA in with a spatial grain size of 15 meters in Imagine format.	May be used to expand area with depth-to-water information.	NA		FGS
Topology	National Elevation Dataset (1/9 arc sec)	NED_1_9th_revisedarea	Shows the elevation (in meters) at a spatial grain of 1/9 arc sec, which is an accuracy of 3 meters where available.	May be used to expand area with depth-to-water information.	NA		NED
Transportation	Major Power Transmission Lines	major_power_transmission.shp	Shows the location of power transmission lines.	Unlikely to be useful.	500	There are a few major power transmission lines located within the study area.	FGDL
Transportation	Major Roads	ROADSGENERALIZED.shp	Shows the major roadways of Florida	Used for presentation purposes.	None	This file alone is insufficient in providing complete roadway information.	FGDL
Transportation	Roads	ROADSDETAILED.shp	Shows all roadways included major and minor	Two shapefiles were downloaded from SWFWMD. The shapefile listed is the most detailed.	None	This file will be best for showing roadways and labeling for more detailed locations.	FGDL
Wildlife	Bald Eagle Nesting Territories	eagle_nests_2009.shp	Shows the status of known Bald Eagle nesting territories through November 2008 to September 2009 nesting seasons.	Buffer nests by 660 feet and exclude areas from suitable sites.	660	There are several Bald Eagle nests within the study area. The Bald Eagle is a threatened species.	FGDL
Wildlife	Florida Panther Focus Area	fa_panther.shp	Shows an area of concern for impacts on the Florida Panther. If a project is located within the focus area the FWC must be notified.	None	NA	The study area does not fall within the focus area and the FWC does not need to be notified.	FGDL
Wildlife	Florida Wood Stork Nesting Colony Core Foraging Areas	woodstork_areas.shp	Shows Florida Wood Stork core foraging areas	Include in write-up that study area contains core foraging areas.	0	It appears the areas of Woodstork foraging is a radius of possible sightings and includes several areas overlapping that cover the entire study area. The Wood Stork is endangered.	FGDL
Wildlife	Red Cockaded Woodpecker (Active and Inactive 2005)	rc_woodpecker_2005.shp.xml	Shows areas of Red Cockaded Woodpecker occurrences	None	500	There are no known occurrences of the Red Cockaded Woodpecker within the study area. The Red Cockaded Woodpecker is an endangered species and is known to reside in the Polk County area (DEP_SpeciesList.pdf).	FGDL
Wildlife	Scrub Jay Habitat	scrubjay_hab_1993.shp	Shows the Florida Scrub Jay populations and their habitat in existence as of 1992-1993.	Exclude from suitable sites.	0	There are several Scrub Jay Habitats within the study area located on the far edges of the study area. The Florida Scrub Jay is an endangered species.	FGDL
Wildlife	Snail Kite Consultation Area	ca_snail_kite_jul11.shp	Shows an area of concern for impacts on the Snail Kite. If a project is located within the focus area the FWC must be notified.	Include in write-up that study area is within consultation area.	500	The study area falls within the consultation area. The FWC may need to be notified about plans for project depending on habitat impacts.	FGDL
Wildlife	Watersheds Containing Rare and Imperiled Fish	rarimpwaters.shp	Shows watershed locations of rare and imperiled fish	None	500	There are no watersheds with rare or imperiled fish located within the study area.	FGDL

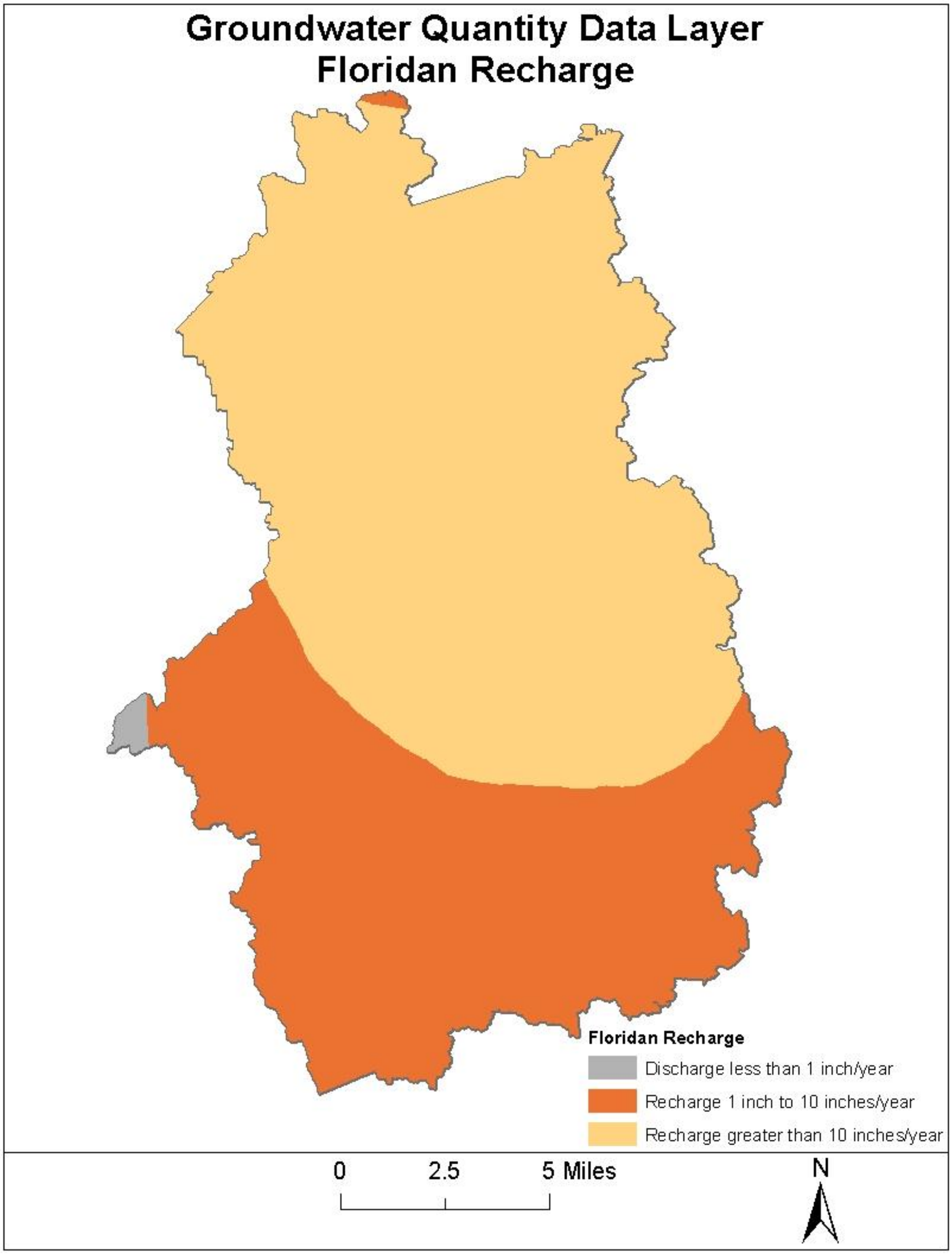
Sources:

EPA	[illegible]
FGDL	[illegible]
FGS	[illegible]
FGS	[illegible]
FDEP	http://www.dep.state.fl.us
NED	http://ned.usgs.gov/
Polk County Property Appraiser	www.polkpa.org/
SWFWMD	http://www.swfwmd.state.fl.us/[illegible]

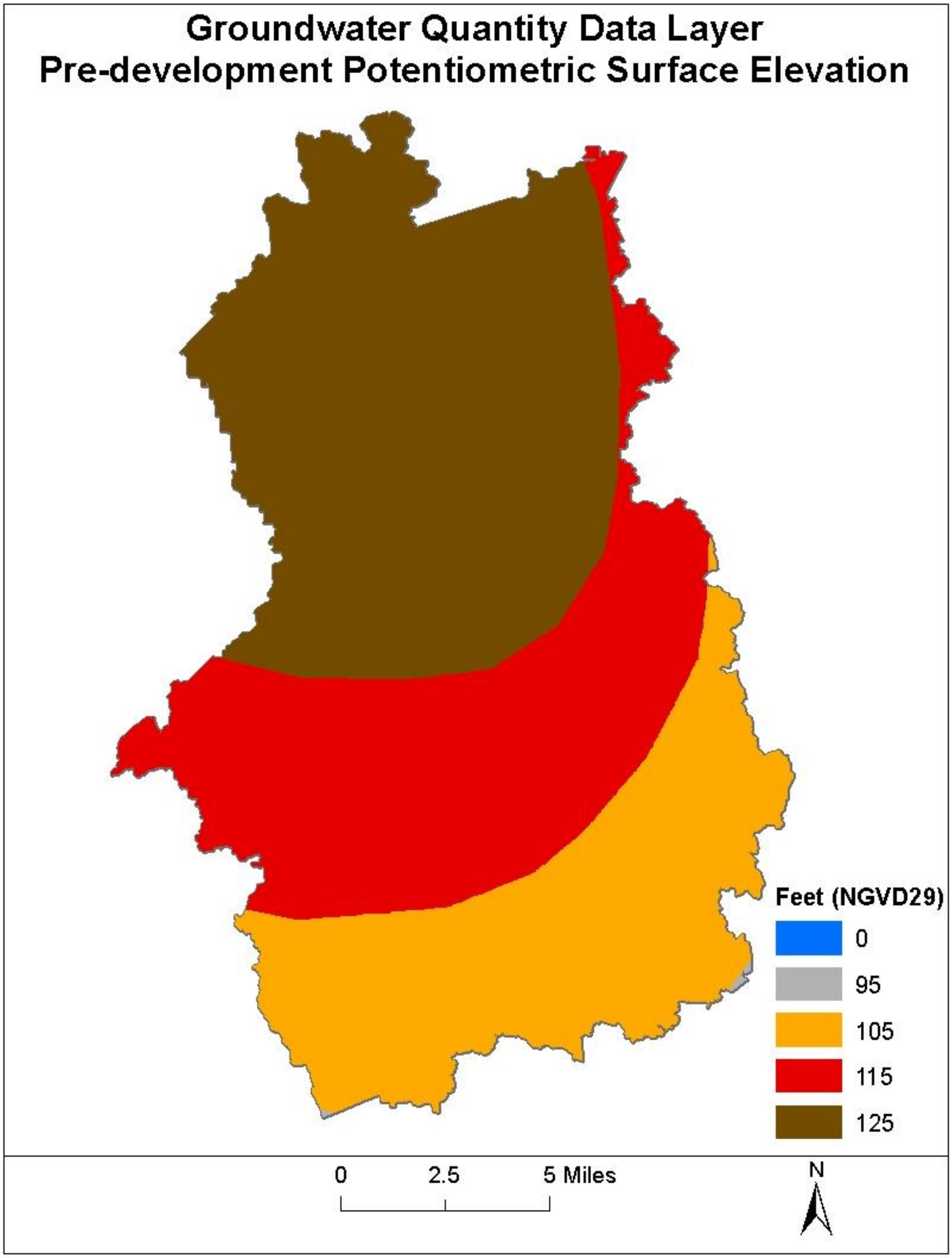
Class	File Name	Shapefile Name	Description	Suggested Approach	Proposed Buffer (feet)	Comments	Data Source
Ground water quality		groundwater	Groundwater data collection sites layer created from water management information system (WMIS) sites data.	Unlikely to be useful		Monitoring site locations can be identified with the shapefile and then the sites can be further researched via the SWFWMD Water Management Information System (WMIS), located at http://www6.swfwmd.state.fl.us/WMIS/ResourceData/ExtDefault.aspx	SWFWMD
Ground water quantity	Geology	Environmental Geology	Environmental Geology of Florida	Was used for verification		Was used for verification	FDEP
Ground water quantity	Groundwater levels	Groundwater	Groundwater data collection sites	Unlikely to be useful		Inadequate for use in this analysis	SWFWMD
Ground water quantity		wucas	Boundary of the Water Use Caution Areas	Unlikely to be useful		Used potentiometric surface as proxy	SWFWMD
Ground water quantity	Aquifer Vulnerability	DRASTIC_FLORIDIAN_AQUIFER	Drastic maps are most useful as a generalized tool to assess regional potential aquifer vulnerability.	Unlikely to be useful		Not for use as a site specific tool.	FDEP
Ground water quantity		DRASTIC_INTERMEDIATE_AQUIFER		Unlikely to be useful		Not for use as a site specific tool.	FDEP
Ground water quantity		DRASTIC_SURFICIAL_AQUIFER		Unlikely to be useful		Not for use as a site specific tool.	FDEP
Habitat	LIDAR	2005 LIDAR	LIDAR, breaklines, 1-ft contours	Unlikely to be useful		LG has this data	Woolpert, Inc.
Habitat	Wetlands	NWI	Wetlands	Unlikely to be useful		Used 2009 land use for wetlands.	USFWS
Habitat	Priority habitats	SHCA	Strategic Habitat Conservation Areas Priority Rankings - 2009	Used in habitat layer		Could not link to data through FFWCC website	FFWCC
Habitat	Land use/cover	lu09.shp	Land use and land cover	Used in conjunction with other data		Combine with other data	SWFWMD
Habitat	Species Locations	Multiple shapefiles available	Specific species locations	Unlikely to be useful		Not applicable for this analysis	FFWCC
Habitat	Habitat and Range Maps	Multiple shapefiles available	Habitat for specific species	Unlikely to be useful		Not applicable for this analysis	FFWCC
Habitat	Florida Forever	Florida Forever	Lands proposed for acquisition because of outstanding natural resources, opportunity for natural resource-based recreation, or historical and archaeological resources	Unlikely to be useful		Not applicable for this analysis	FFWCC
Habitat	Historic LandUse/Land Cover	lu_usgs_1974.shp	This data set depicts land use and land cover from the 1970s and 1980s. Land-use and land-cover data collected by the U.S. Geological Survey are useful for environmental assessment of land-use patterns with respect to water-quality analysis, growth management, and other types of environmental impact assessment.	Unlikely to be useful		Used historical land use and land cover data from the 1940s.	USGS
Source Water Quality	Water Quality Data	WATER_QUAL_3058_2000	2002 Statewide coverage of water quality data created by the Watershed Planing and Coordination Section	Unlikely to be useful		Used more updated data.	FDEP
Source Water Quality	IWR	IWR	Impaired Waters Rule	Used for reference		Used for reference	FDEP
Source Water Quality	WBID boundaries	WBID_Run40.shp	WBID shapefiles	Used for water quality status data.		Used for water quality status data.	FDEP
Source Water Quality	ERPs	erp	Environmental Resource Permit Conservation Application polygon boundaries	Unlikely to be useful		Not applicable for this analysis	SWFWMD
Source Water Quantity	FEMA boundaries	DFIRM_FLDHAZ_JUL11.shp	Flood hazard zones of the Digital Flood Insurance Rate Map	Unlikely to be useful		Not applicable for this analysis	FEMA
Source Water Quantity	Flood zones	DFIRM_FLDHAZ_JUL11.shp	Flood hazard zones of the Digital Flood Insurance Rate Map	Unlikely to be useful		Not applicable for this analysis	FEMA
Topography	Topography	amtopo.shp	Photogrammetrically collected one- and two-foot topographic contours and spot elevations	Unlikely to be useful		Contact the Mapping and GIS Section at (352) 796-7211	SWFWMD

Appendix B. Mapped Data Layers Used in Development of Resource Targets.

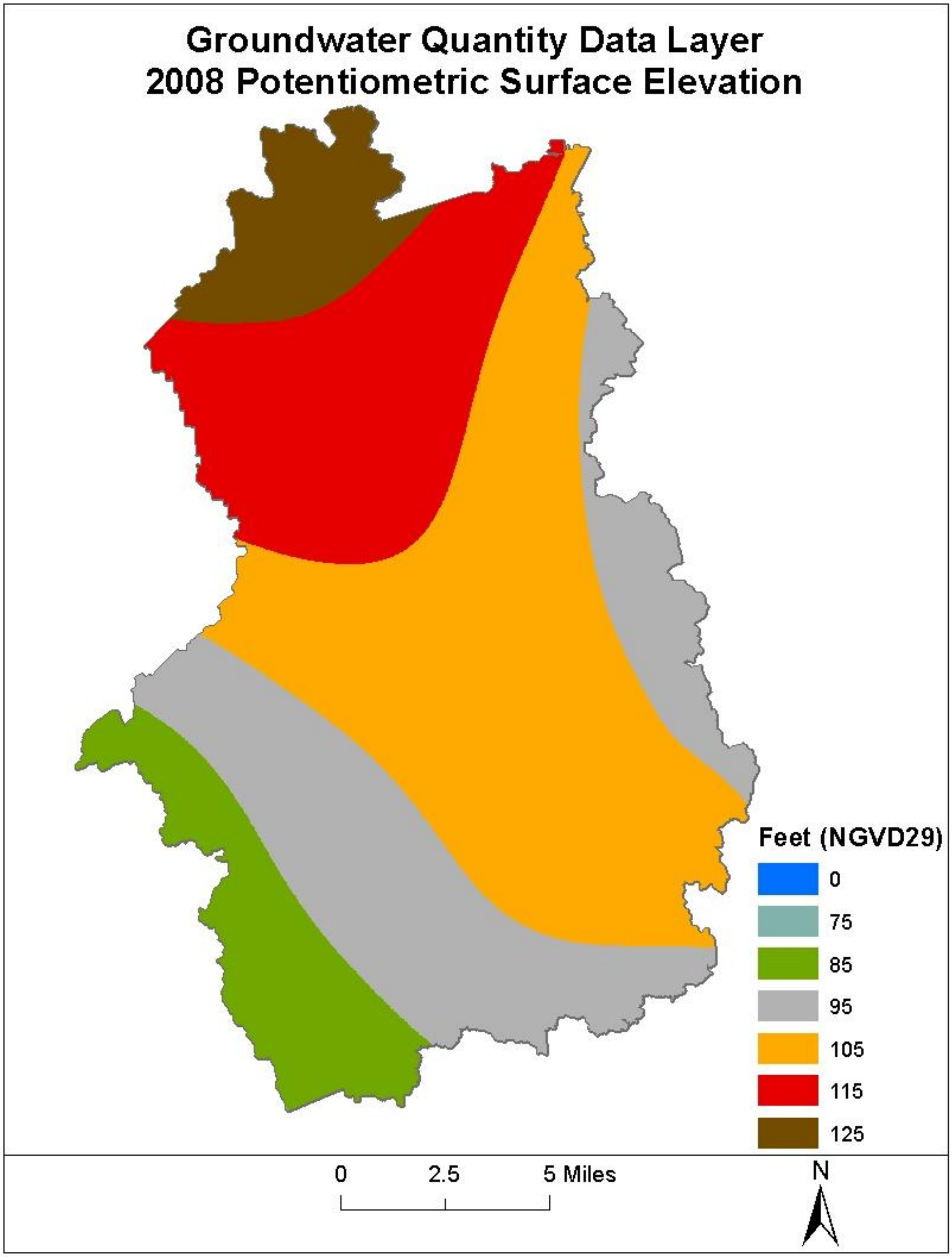
B.1. Groundwater Quantity Data Layer: Floridan Recharge



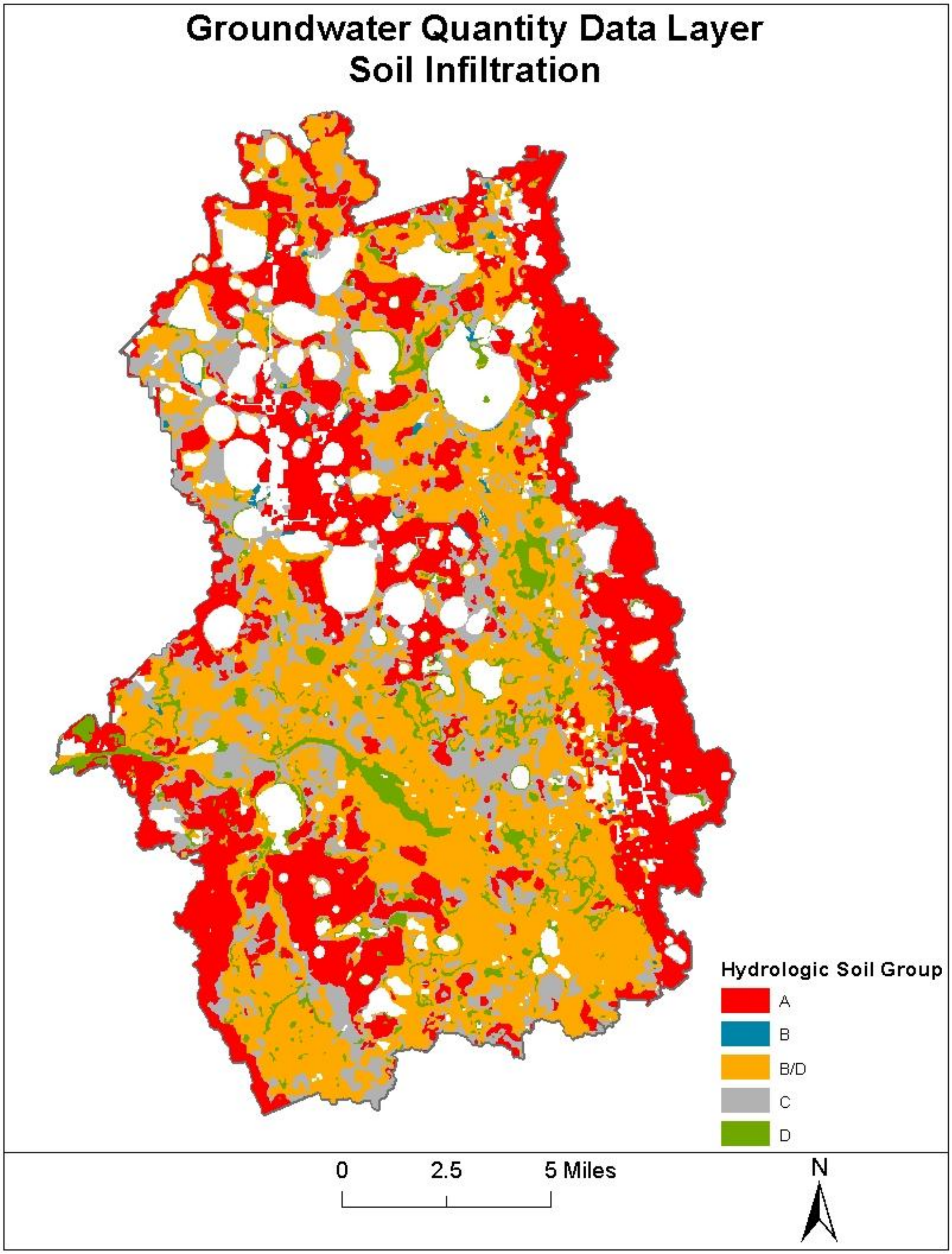
B.2. Groundwater Quantity Data Layer: Pre-Development Potentiometric Surface Elevation



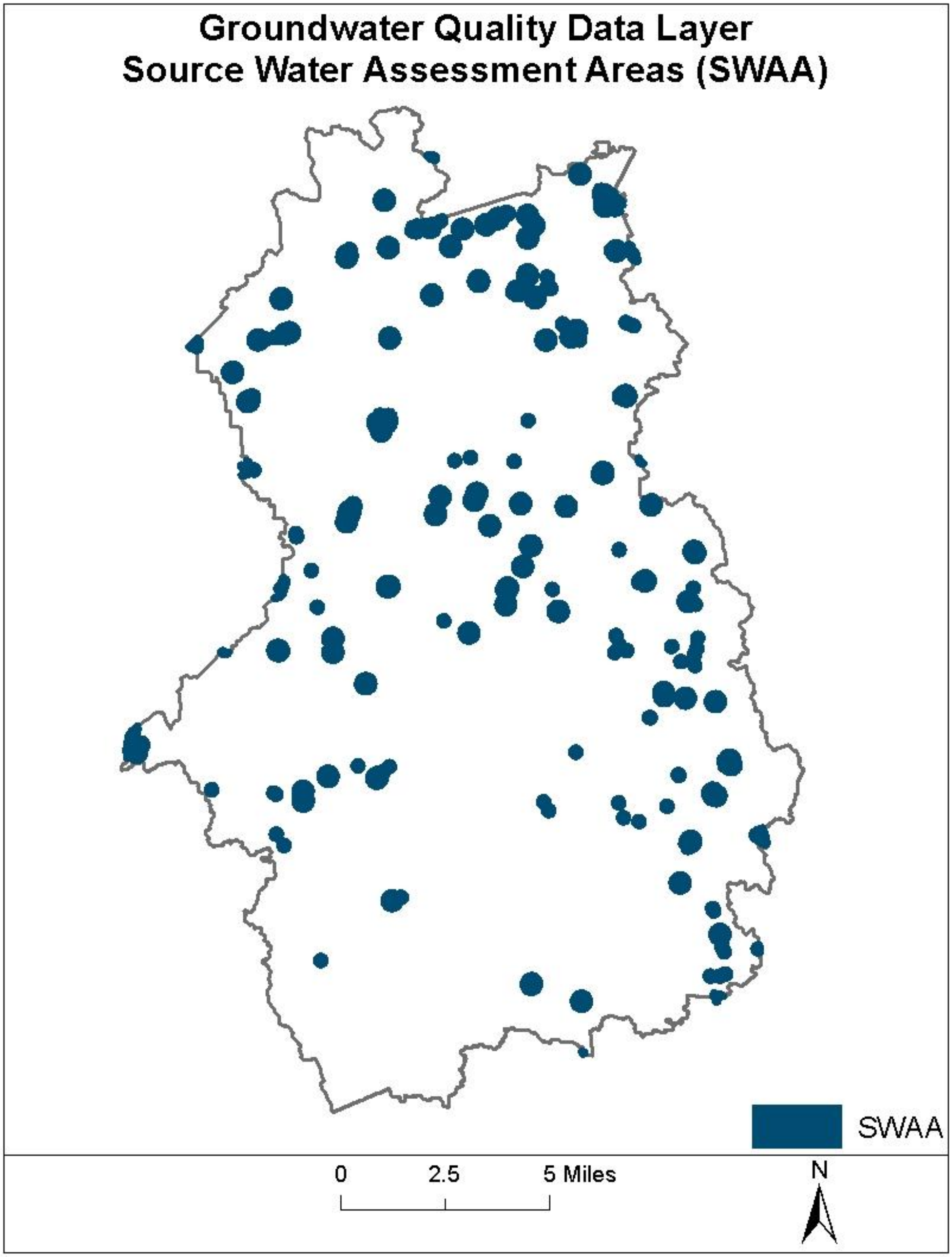
B.3. Groundwater Quantity Data Layer: 2008 Potentiometric Surface Elevation



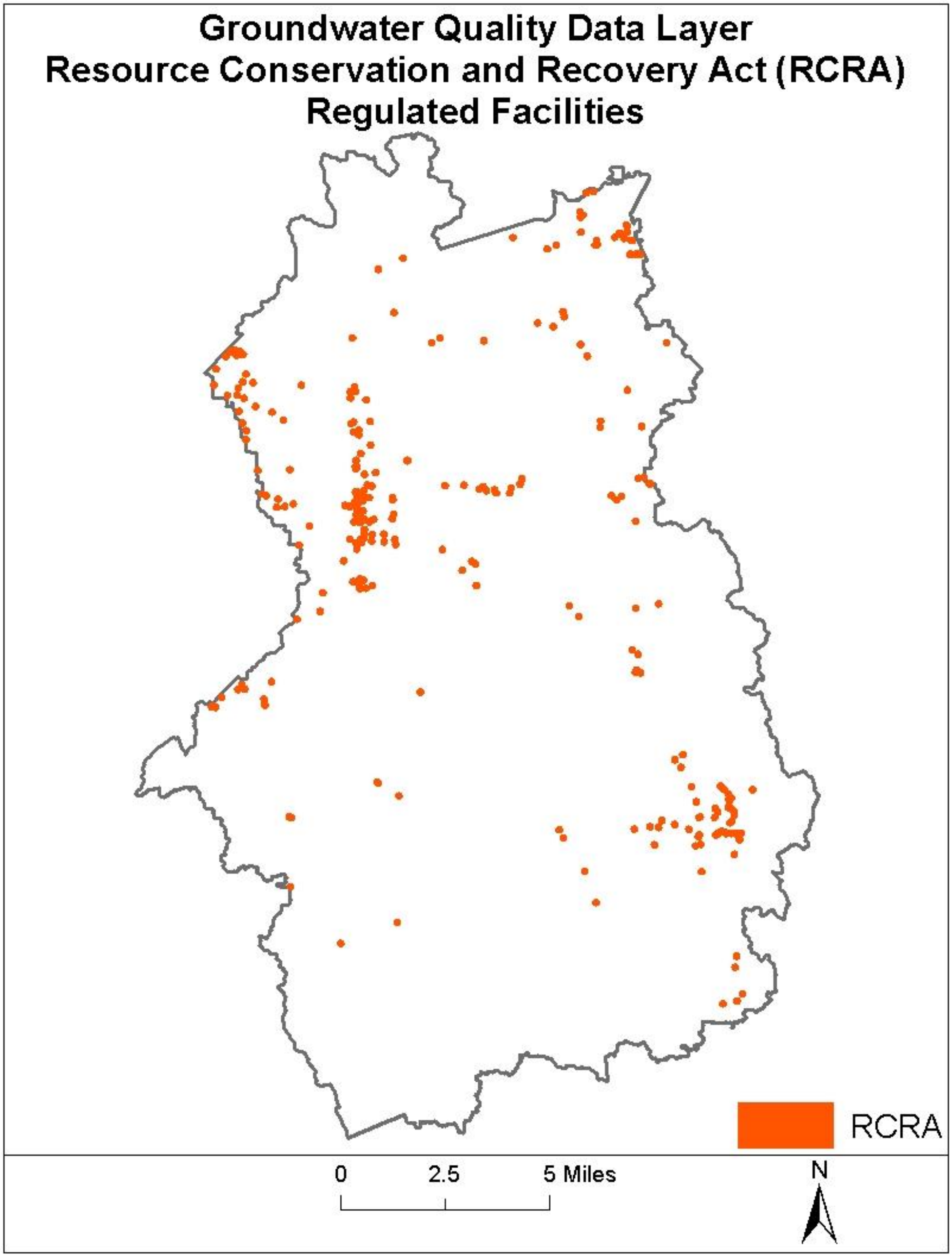
B.4. Groundwater Quantity Data Layer: Soil Infiltration



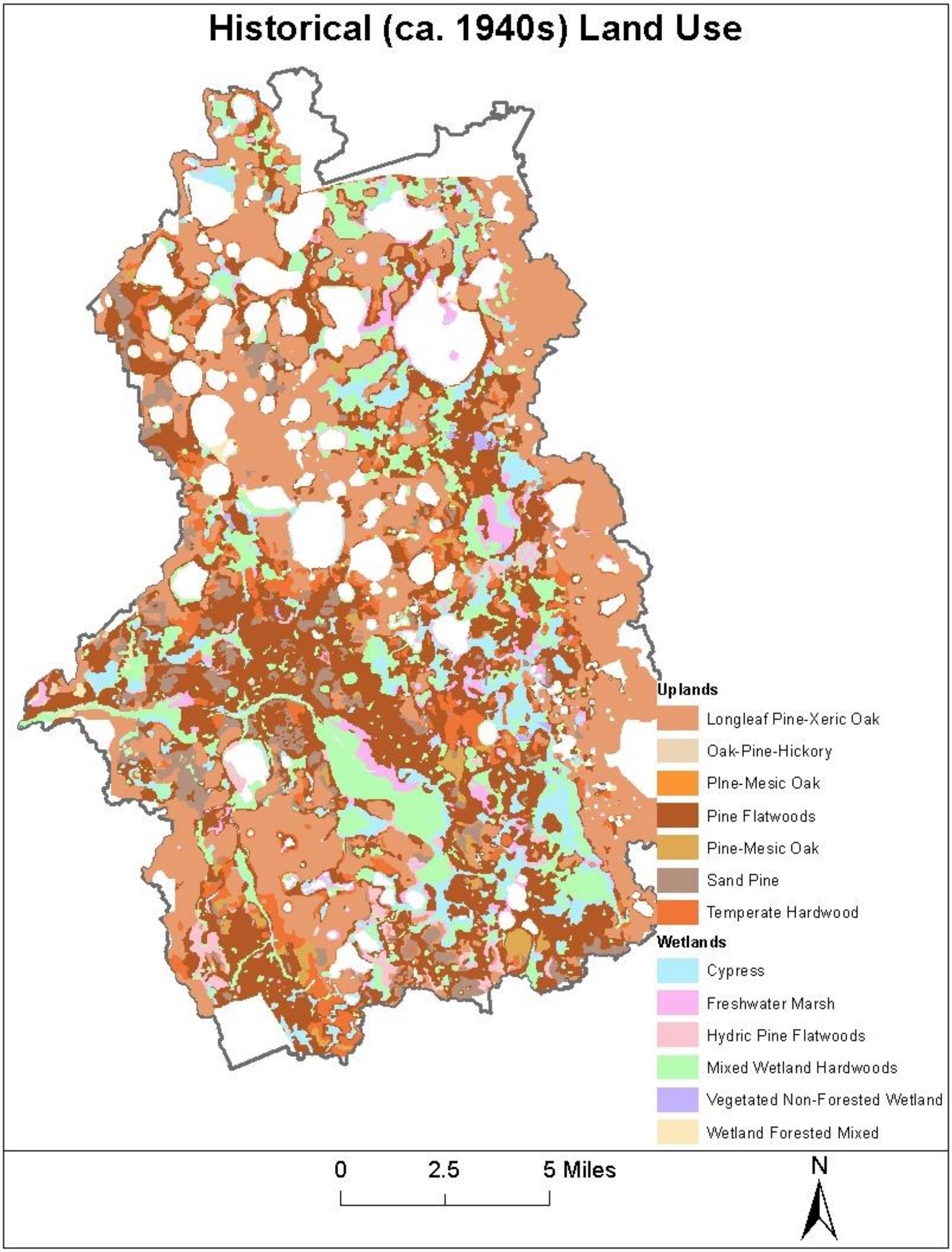
B.5. Groundwater Quality Data Layer: Source Water Assessment Areas



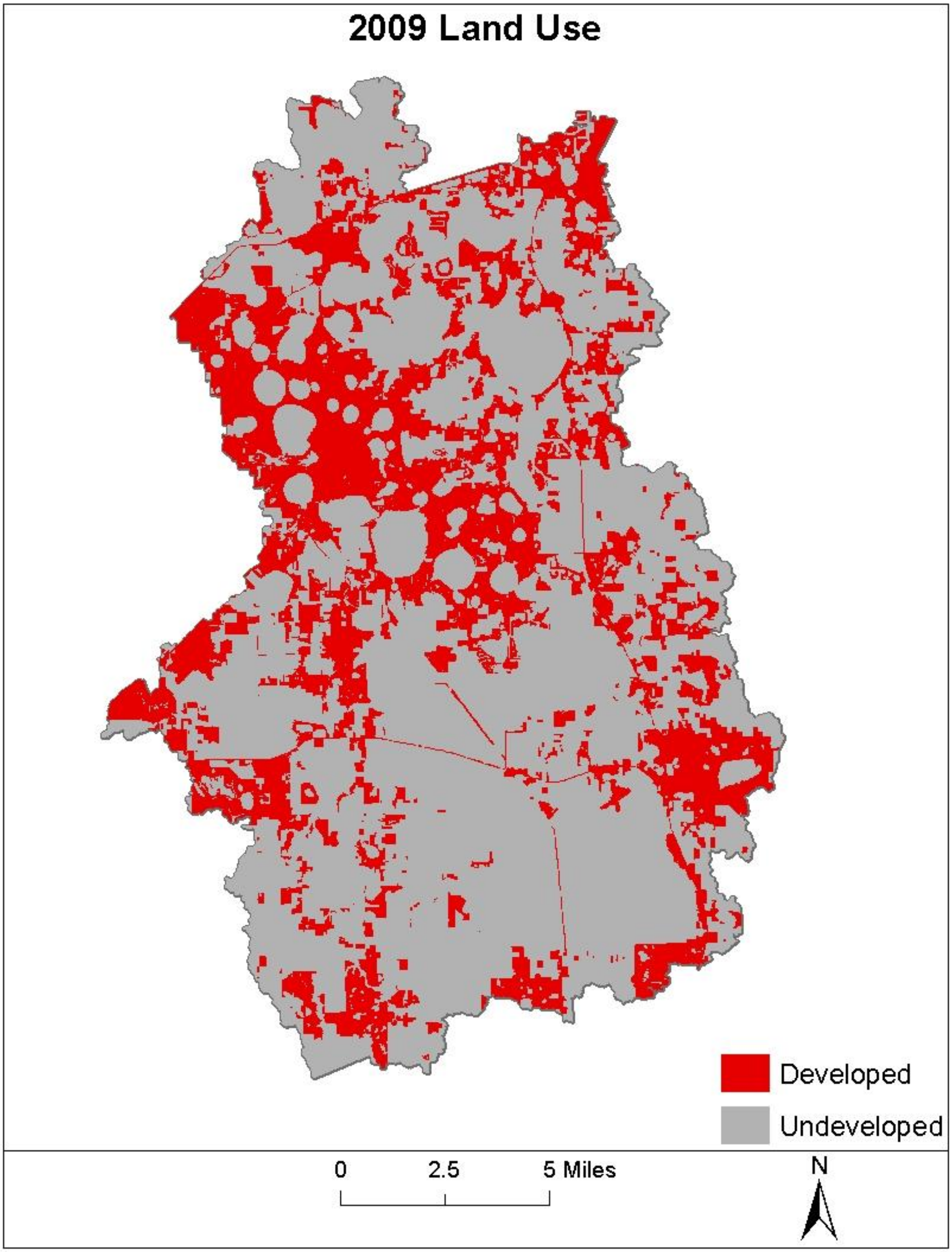
B.6. Groundwater Quality Data Layer: RCRA



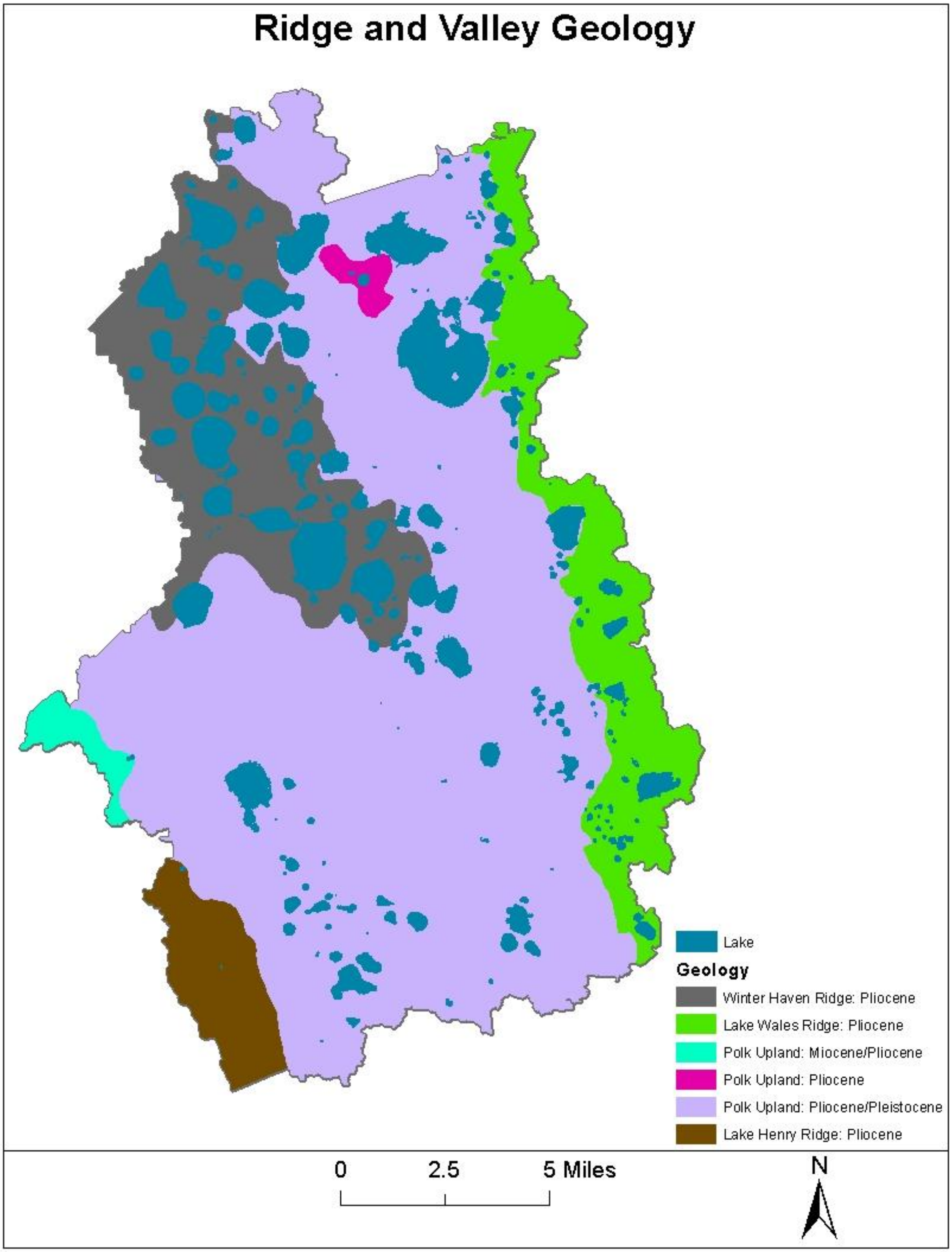
B.7. Historical (circa 1940s) Land Use



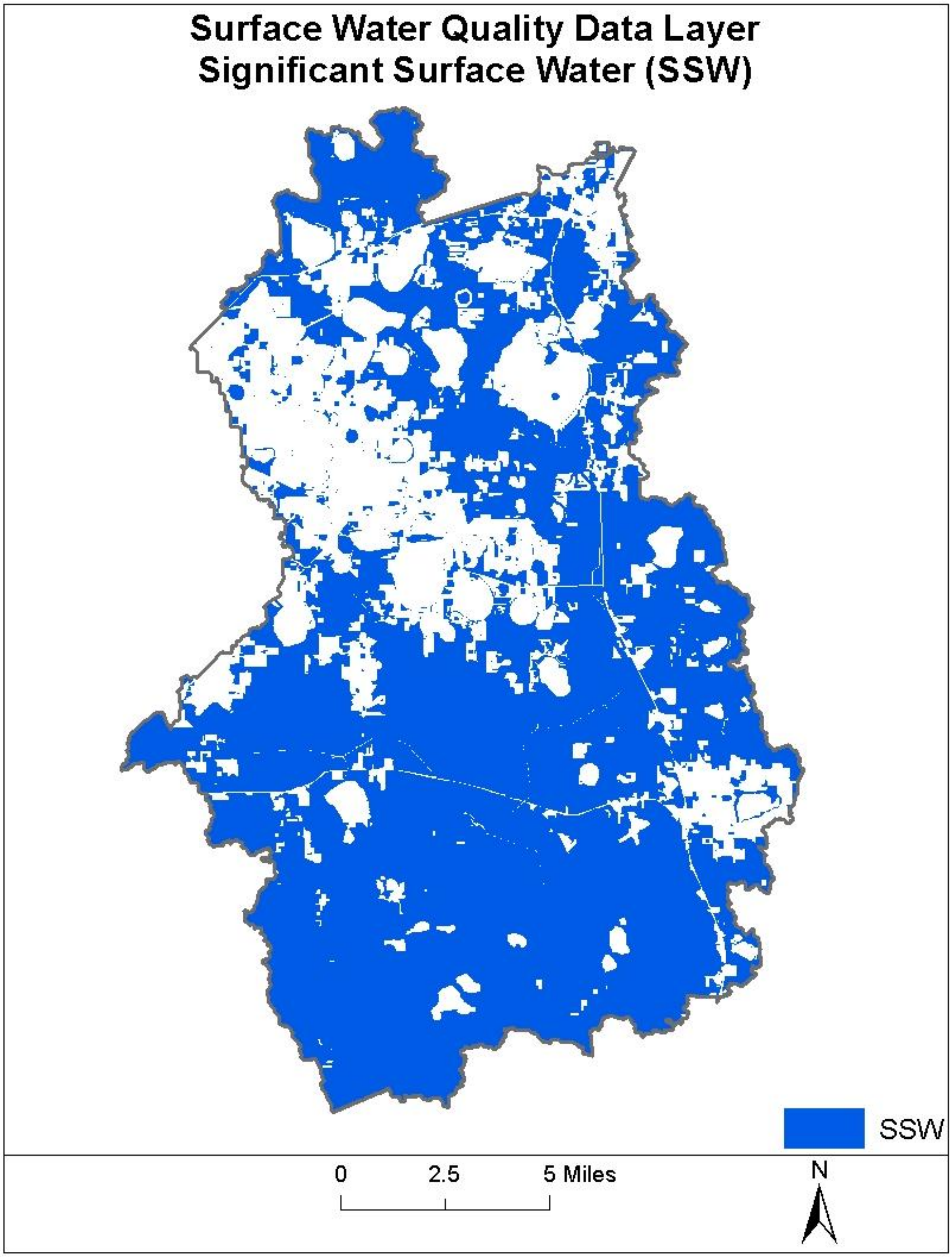
B.8. Current (2009) Land Use



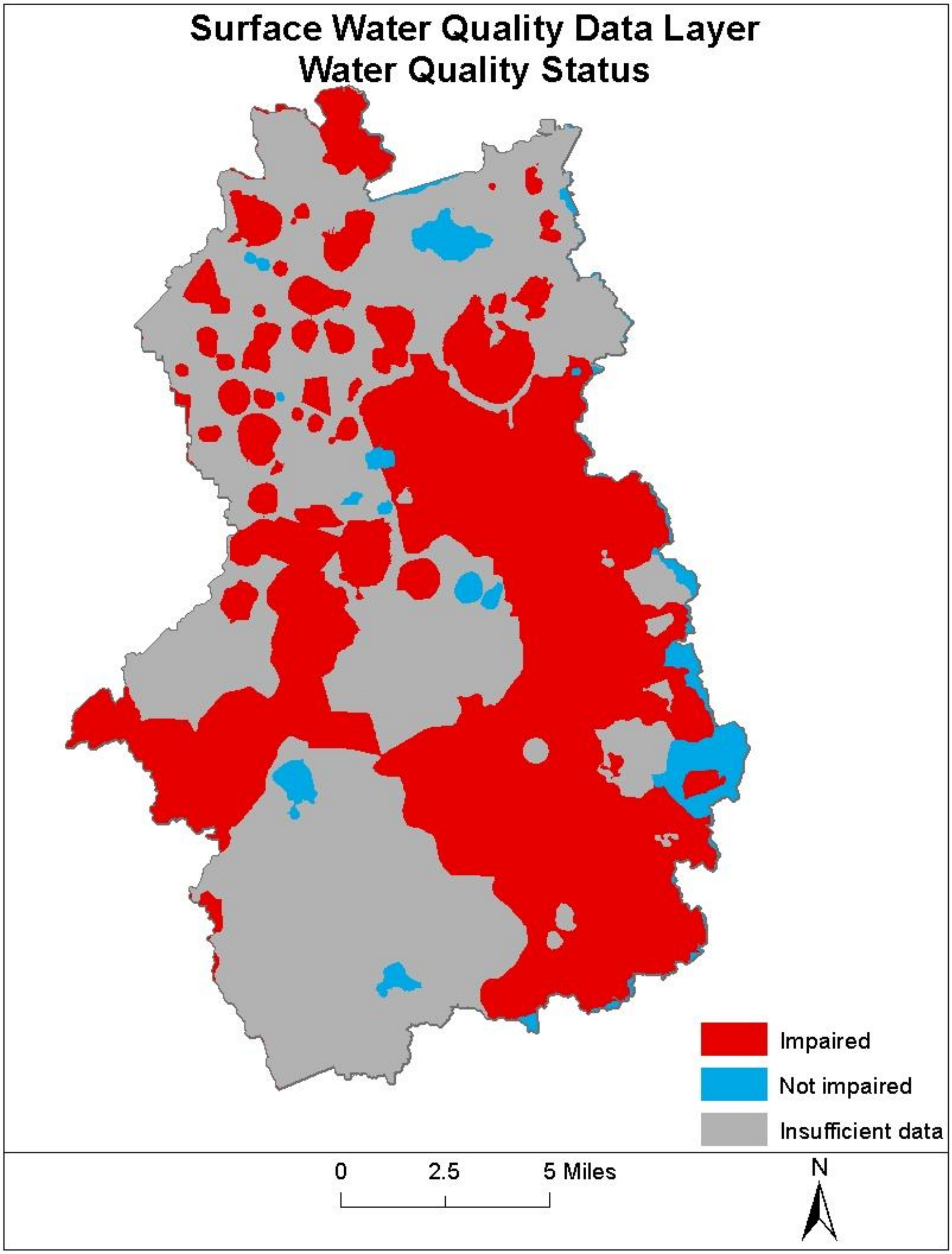
B.9. Ridge and Valley Geology



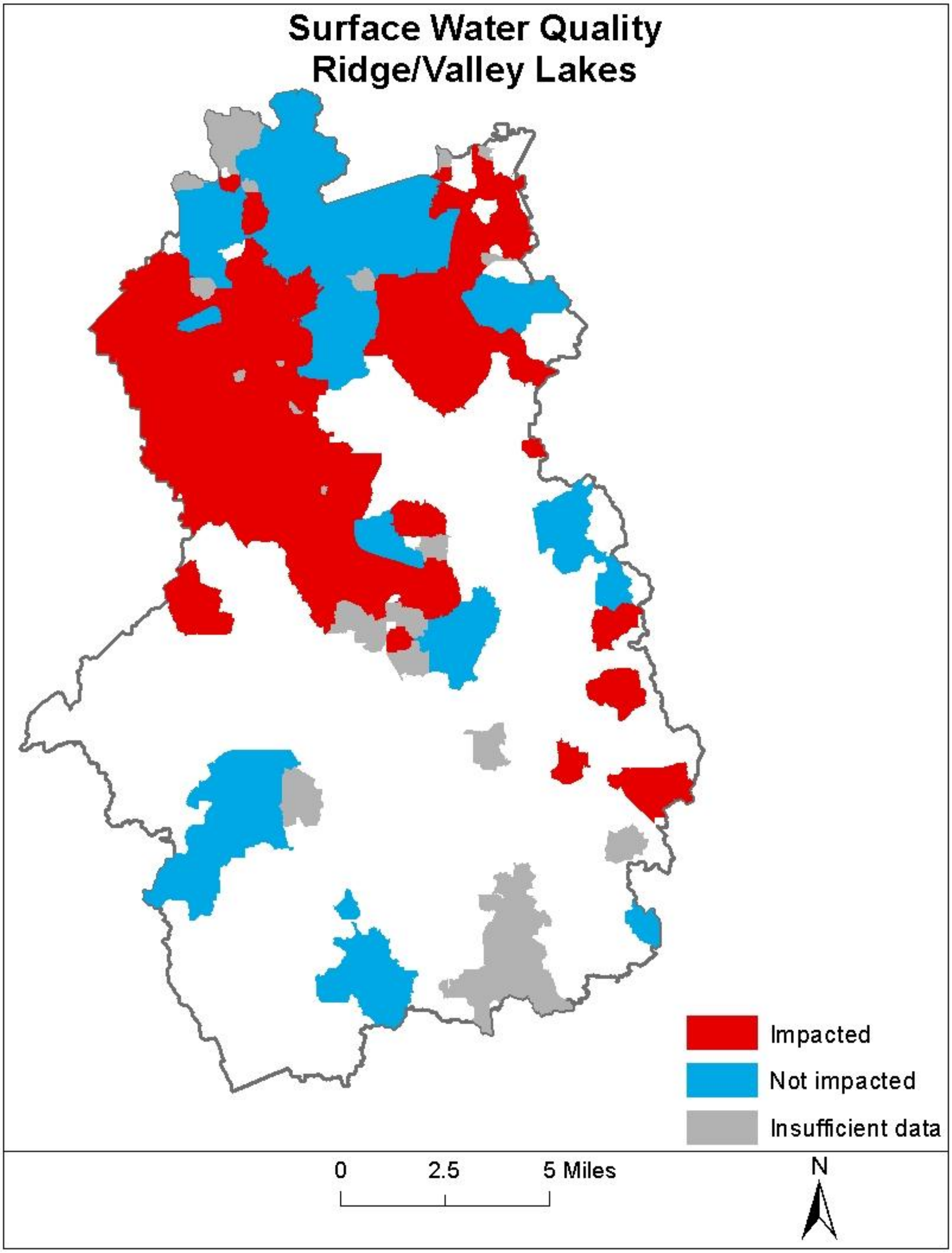
B.10. Surface Water Quality Data Layer: Significant Surface Water



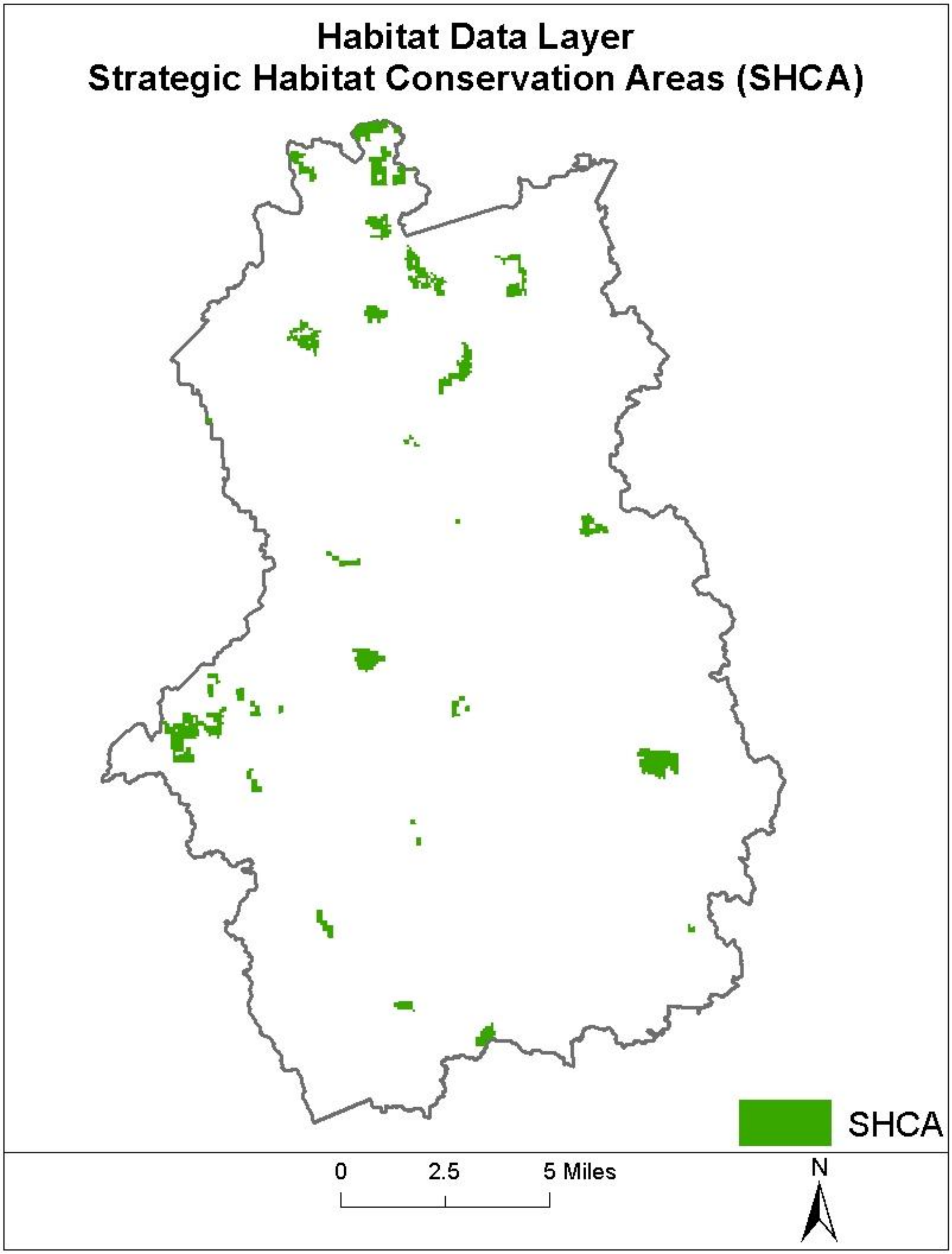
B.11. Surface Water Quality Data Layer: Water Quality Status



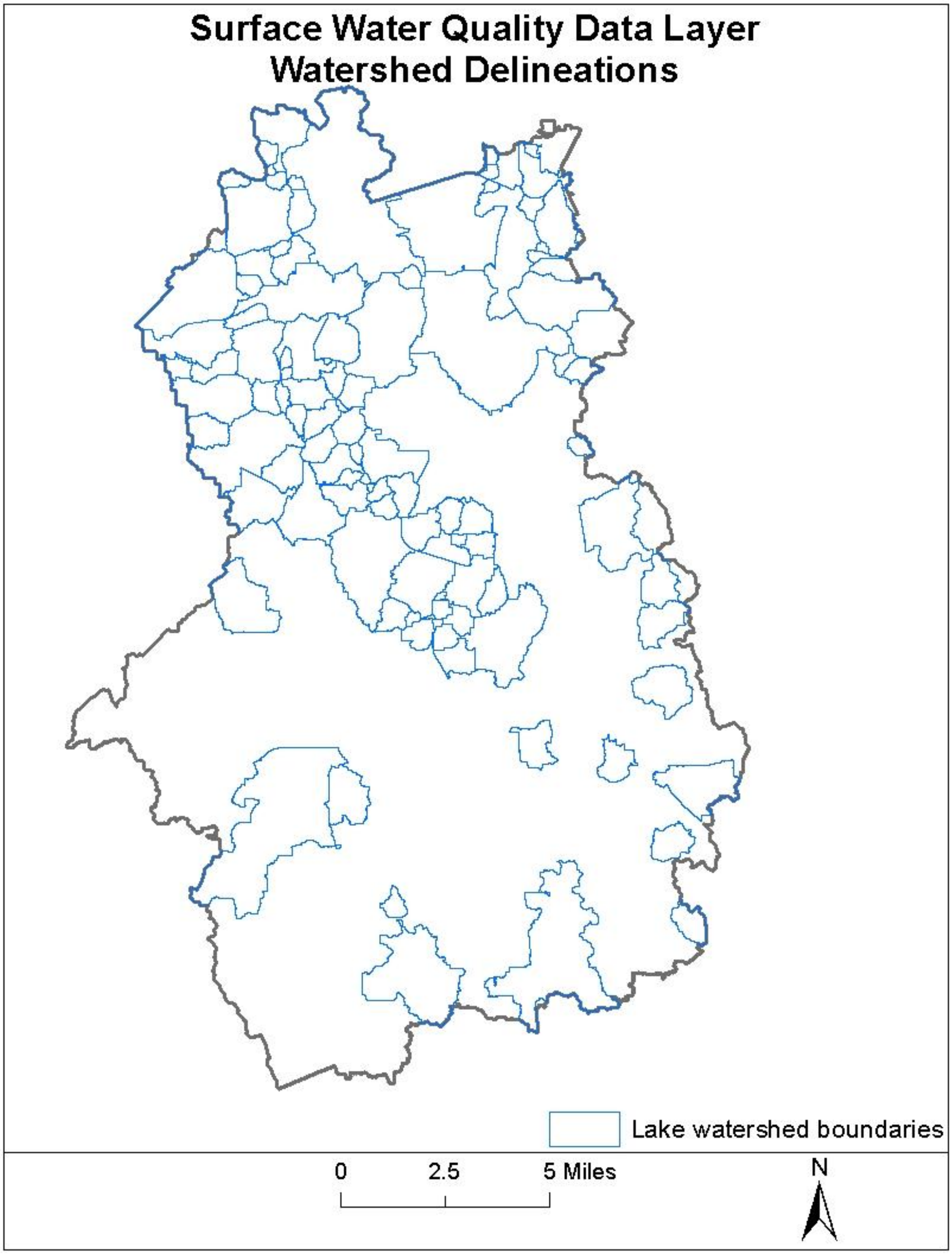
B.12. Surface Water Quality: Ridge/Valley Lakes



B.13. Habitat Data Layer: SHCAs

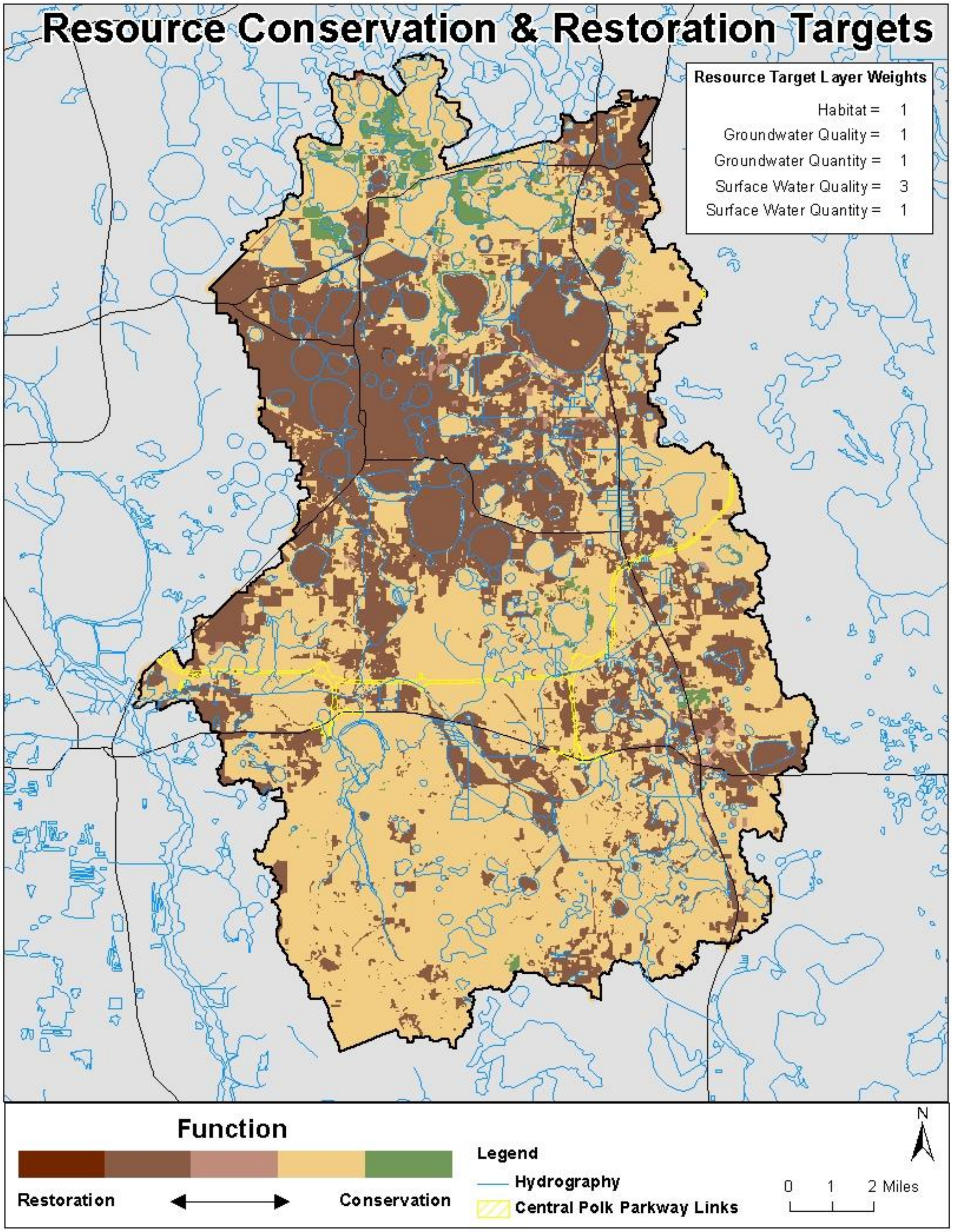


B.14. Surface Water Quality Data Layer: Watershed Delineations

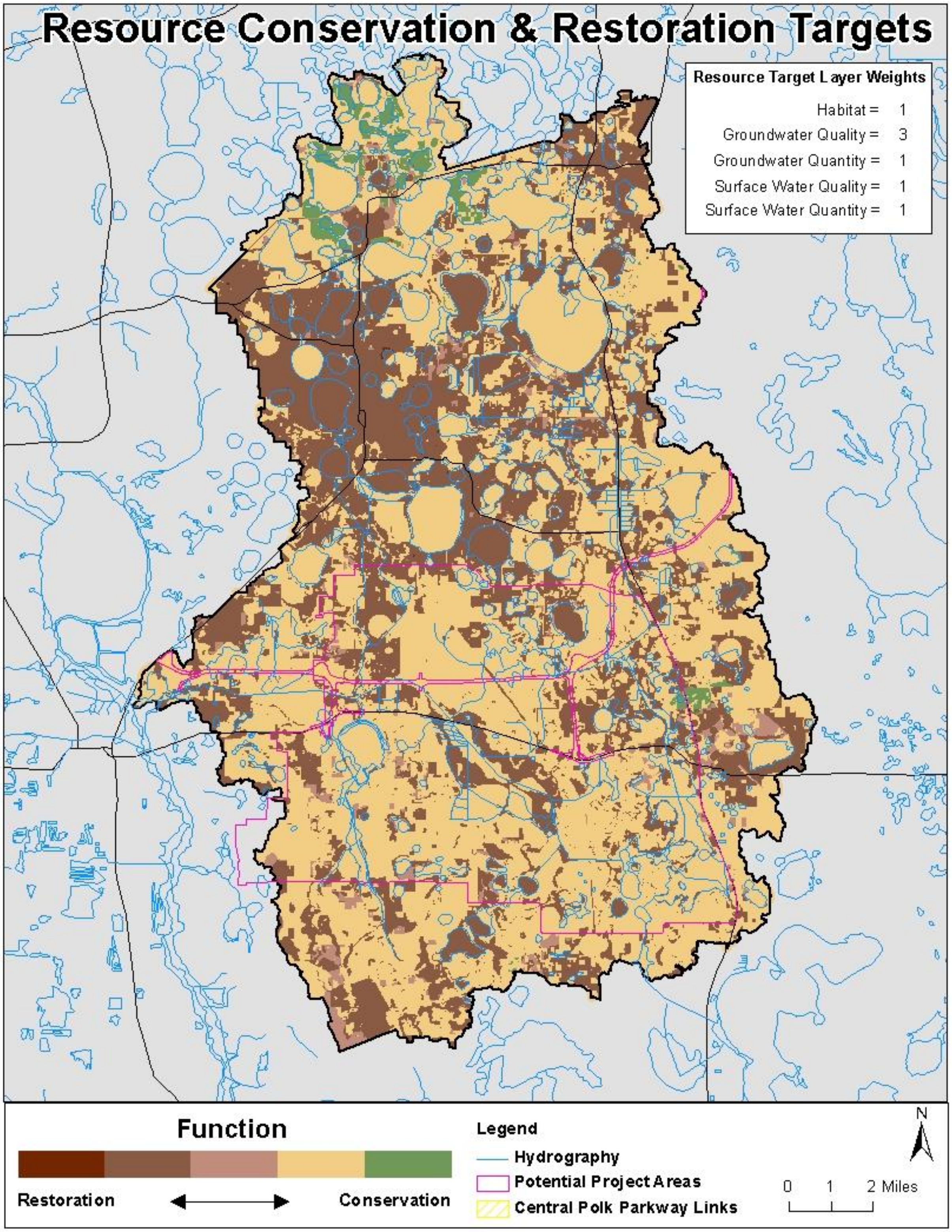


Appendix C. Conservation and Restoration Resource Target Scenarios

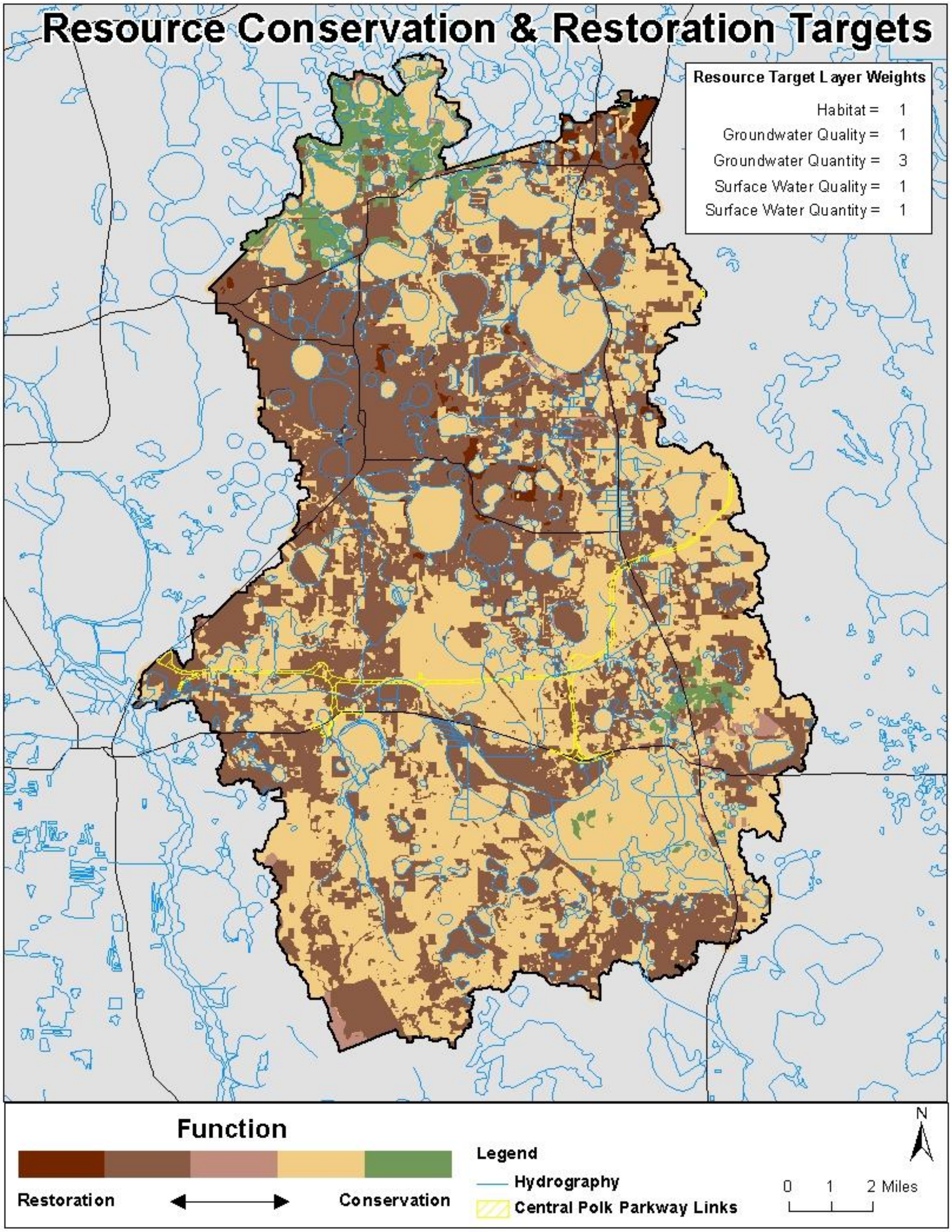
C.1. Conservation and restoration resource target map when surface water quality is assigned a weight of "3" with all remaining resource function layers are assigned equal weights of"1" (Scenario 3).



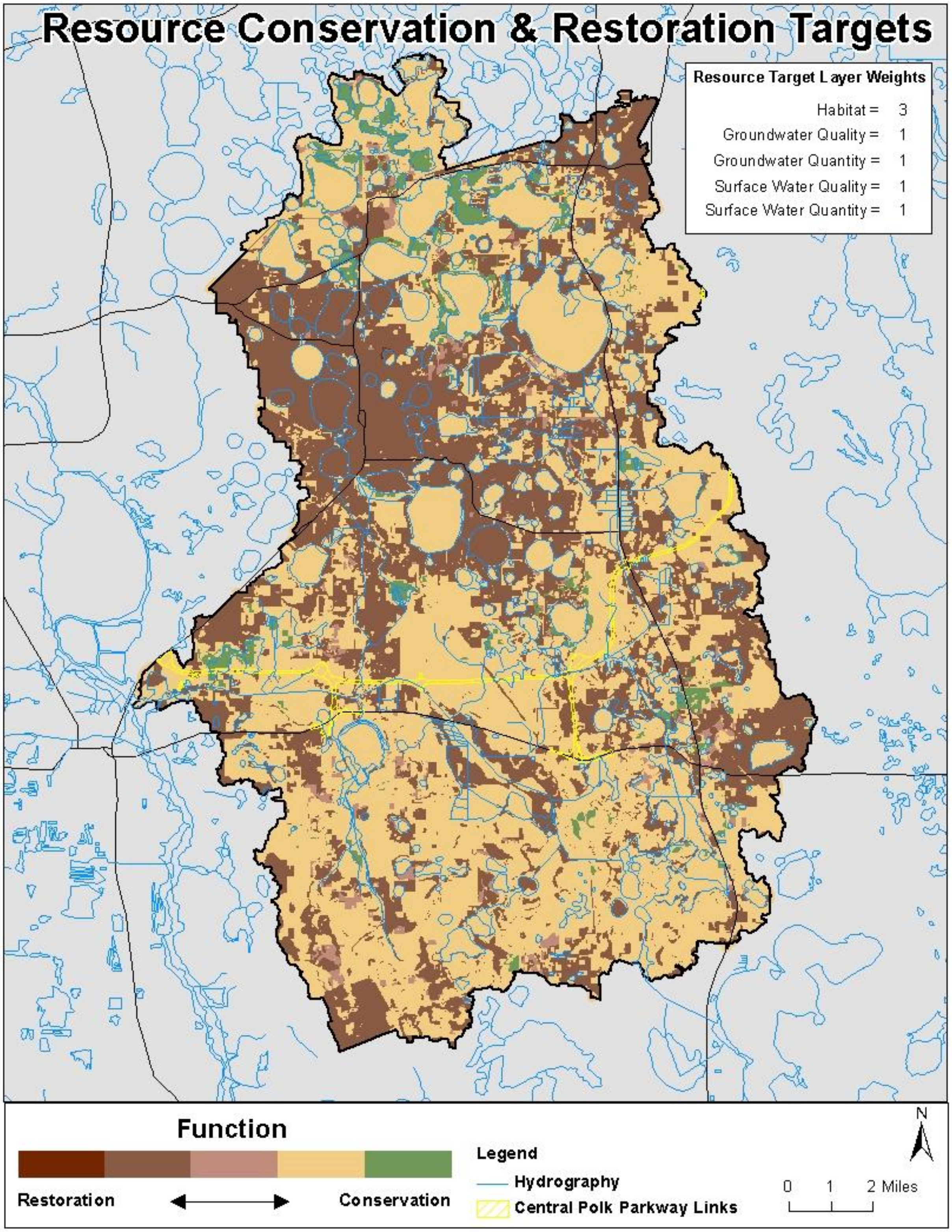
C.2. Conservation and restoration resource target map when groundwater quality is assigned a weight of "3" with all remaining resource function layers are assigned equal weights of"1" (Scenario 4).



C.3. Conservation and restoration resource target map when groundwater quantity is assigned a weight of “3” with all remaining resource function layers are assigned equal weights of”1” (Scenario 5).



C.4. Conservation and restoration resource target map when habitat is assigned a weight of "3" with all remaining resource function layers are assigned equal weights of"1" (Scenario 6).



Pam Latham, Ph.D., PWS, CSE
Atkins
4030 West Boy Scout Boulevard, Suite 700
Tampa, FL 33607

pamela.latham@atkinsglobal.com
Tel: 813.281.8359