

# A GIS DATA LAYER FOR GUIDING DEVELOPMENT COMPATIBLE WITH FIRE MANAGEMENT OF NEIGHBORING CONSERVATION SITES

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## ABSTRACT

To secure the long-term use of prescribed fire as a land management tool, The Nature Conservancy's Lake Wales Ridge Program has developed the Critical Smoke Dispersal Area (CSDA) GIS data layer for conservation sites associated with the Lake Wales Ridge in central Florida, USA. The CSDA data layer is intended as a land-use planning tool that provides guidance for the best locations of new development, according to development type, within 3.22 km (2 mi) from the edge of conservation areas in order to minimize smoke impact from prescribed fires. The spatial model used classifies the area surrounding conservation sites into four stacked buffer zones extending outward from conservation boundaries up to 3.22 km (2 mi). Each zone is suitable for specific types of smoke-sensitive development; development types of greater smoke sensitivity (e.g., interstate highways and hospitals) occur within zones with greater default distances from conservation boundaries than do types less sensitive to smoke (e.g., local rural roads). The distribution of smoke-sensitive development types among the four buffer zones is determined by a set of minimum distance criteria for roads, hospitals, aviation sites, residential and commercial areas, and other smoke-sensitive land uses. These criteria were developed by Nature Conservancy fire managers and reviewed by land managers of Lake Wales Ridge conservation sites. To identify the CSDA areas, a land-use analysis was conducted using ArcGIS Spatial Analyst's cost-weighted distance tool. To minimize fire management constraints resulting from new development, land-use planners can utilize the CSDA as a guide for placement either outside of the CSDA or within the appropriate buffer zones. Thus, if new development must occur within the CSDA, it can be placed in areas along with development of similar smoke sensitivity or at a distance that minimizes its smoke risk. In this way, smoke-sensitive areas can be concentrated, maintaining the low smoke sensitivity of remaining areas. The Conservancy presented the CSDA data to District One of the Florida Department of Transportation, and these data were approved for inclusion into their Efficient Transportation Decision Making process. The Conservancy has also coordinated with the Polk County Land Use Planning Department and the Central Florida Regional Planning Council to incorporate the CSDA into the Polk County Comprehensive Plan.

*Keywords:* Florida, GIS, Lake Wales Ridge, land-use planning, smoke management.

*Citation:* Pace-Aldana, B. 2010. A GIS data layer for guiding development compatible with fire management of neighboring conservation sites. Pages 49–54 in K.M. Robertson, K.E.M. Galley, and R.E. Masters (eds.). Proceedings of the 24th Tall Timbers Fire Ecology Conference: The Future of Prescribed Fire: Public Awareness, Health, and Safety. Tall Timbers Research Station, Tallahassee, Florida, USA.

## INTRODUCTION

Florida's population is projected to double within 50 years, resulting in an increase of urbanized lands within 1.61 km (1 mi) of conservation areas (Zwick and Carr 2006). As rural areas are converted to development, the ability to apply fire safely and effectively on conservation lands will become increasingly difficult. Fire managers may have fewer and fewer days available with the appropriate weather conditions for diverting smoke away from smoke-sensitive development. This scenario risks the creation of a backlog of areas in need of fire, leading to increased fuel loads that diminish native species and increase wildfire risks and exacerbating the negative impacts to the viability of the state's conservation areas that will already have resulted from fragmentation in a sea of urbanization.

To secure the long-term use of prescribed fire as a management tool, The Nature Conservancy's (TNC) Lake Wales Ridge Program has developed the Critical Smoke Dispersal Areas (CSDAs) GIS data layer (Figure 1) for 66 federal, state, county, and private conservation lands associated with the Lake Wales Ridge in central peninsular Florida, USA. The objective for the CSDA data is as a guide for land-use

planning that is compatible with fire management of conservation areas. The CSDA data layer is designed to encourage any new development within 3.22 km (2 mi) of conservation areas to be placed at distances sufficient to minimize smoke risk or near locations with existing development of similar smoke sensitivity. In this way, the existing areas of low smoke sensitivity within the CSDA can be preserved.

The CSDA consists of all areas potentially within smoke buffers extending to a maximum of 3.22 km (2 mi) from the edge of a conservation area. For this project, TNC defines a smoke buffer as the area devoid of smoke-sensitive land uses surrounding a prescribed fire or where the smoke-sensitive areas are at a sufficient distance to pose minimal smoke risk. TNC fire managers at the state and local levels identified 3.22 km (2 mi) as the distance at which roads and development most constrain fire management (W. Thomson and S. Morrison, TNC, personal communication); therefore, a maximum distance of 3.22 km (2 mi) from conservation boundaries defined the target area for the land-use analysis and guidelines defining the CSDA.

Ideally, to maximize the use of prescribed fire and minimize smoke risk to human life and property, new developments would be limited to outside of the CSDA. However, a recommendation that no additional roads, road expansions, or developments occur anywhere within 3.22 km (2 mi) of a conservation area would likely be unacceptable to land-use

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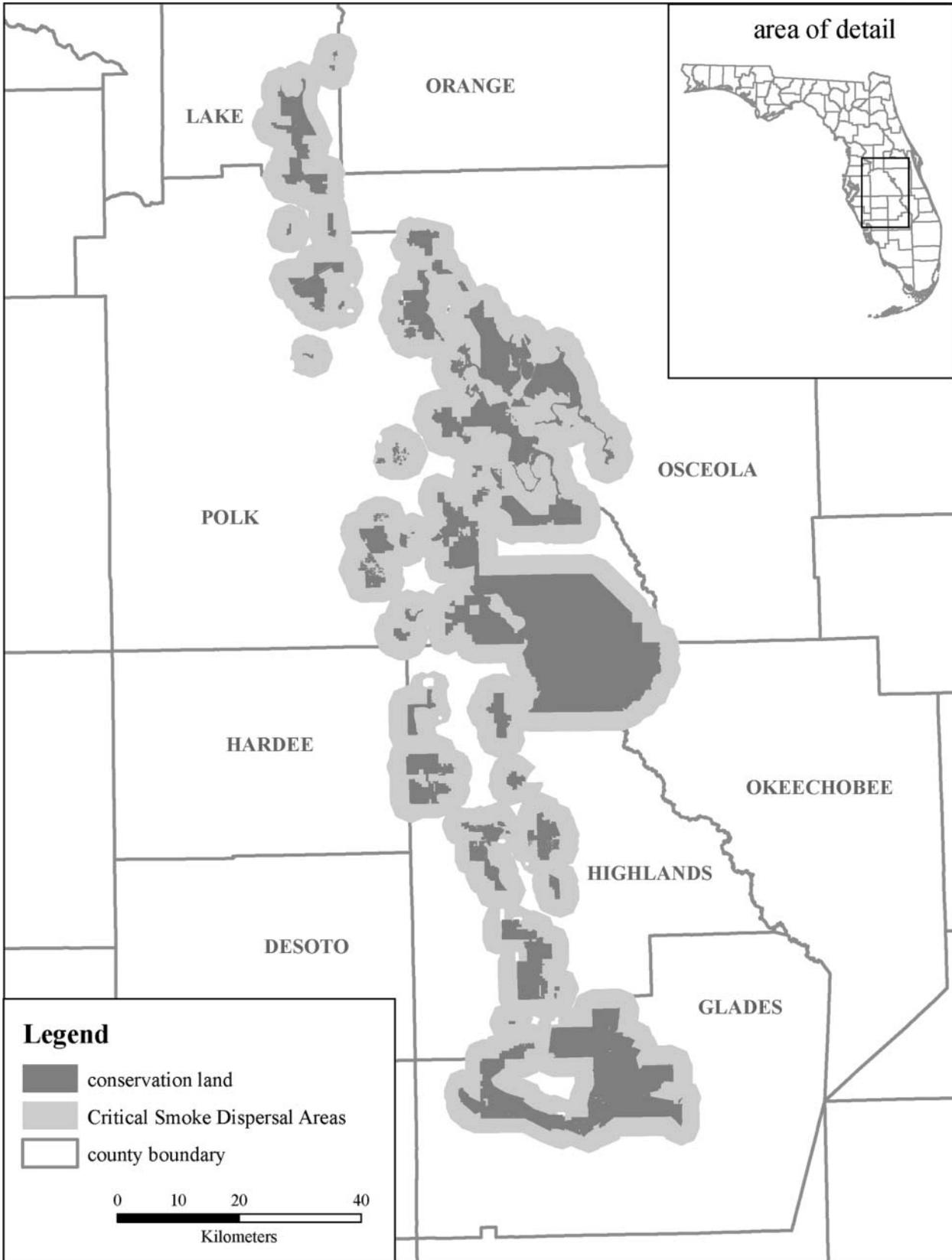


Figure 1. The Critical Smoke Dispersal Areas for conservation lands associated with the Lake Wales Ridge in central Florida, USA.

planners. Therefore, TNC developed criteria for appropriate placement of new development within the CSDA. The criteria, developed by TNC fire managers from the Lake Wales Ridge and the Florida Chapter, consist of minimum distances from conservation boundaries for development types of different levels of smoke sensitivity (Table 1). These criteria were submitted to land managers of the conservation sites within the CSDA and received general approval. The development types consist of roads by Florida Department of Transportation (FDOT) functional class, hospitals, nursing homes, airports and other aviation sites, and commercial, residential, and industrial areas. Development types of greater smoke sensitivity (e.g., interstate highways) have a higher recommended minimum distance than development types less sensitive to smoke (e.g., a local rural road).

To identify the areas for suitable placement of development, the CSDA area is classified into four stacked buffer zones, each suitable for specific types of smoke-sensitive development (Figure 2). The buffer zones are numbered 1 through 4, reflecting increasing suitability for development types of greater smoke sensitivity (i.e., development types of greater smoke sensitivity are limited to zones of higher value than are development types of lesser smoke sensitivity). To preserve the smoke buffers captured within the CSDA, land-use planners would allow new roads, road expansions, and developments only within the appropriate buffer zones (Table 1). For example, a new hospital should occur only within an area classified as buffer zone 4; a new local-rural road should be sited within a buffer zone 2 or higher. Thus the CSDA is a user-friendly planning tool with an easy-to-read graphical presentation of the most flexible options possible for development with limited constraints to fire management.

Where developments occur at less than the minimum recommended distances, the category, location, and width of the buffer zones are determined by the existing development types and their distances from the nearest conservation edge.

For example, where a residential, commercial, or industrial area occurs immediately adjacent to a conservation boundary, the area is classified as a zone 2 at best (Figure 2). Where there are no developments extending at a perpendicular distance from a conservation edge or where all developments are at or exceed the recommended distances, the buffer zones are at their full width from the nearest conservation boundary. The default maximum buffer zone widths are 0.402 km (0.25 mi) for each of buffer zones 1 and 2, 805 m (0.5 mi) for buffer zone 3, and 1.609 km (1 mi) for buffer zone 4.

A conservation property with a CSDA compromised by smoke-sensitive development in too close proximity may have one or more buffer zones narrower than the maximum width or may be missing one or more zones altogether. Land managers may have to contend with such scenarios by using other conservation areas adjacent to burn units as part of the smoke buffer or take other special precautions while planning and executing prescribed burns. The CSDA data layer was originally developed as part of the Greater Ridge Conservation Planning Tool (GRCPT), which is a joint project of TNC’s Lake Wales Ridge Program (Babson Park, Florida), Archbold Biological Station (Lake Placid, Florida), and the GeoPlan Center in the University of Florida’s College of Design, Construction and Planning (Gainesville, Florida). The goal of the GRCPT is to ensure the viability of the Lake Wales Ridge conservation network by identifying critical areas for the movement of wildlife, the application of prescribed fire, the protection of watersheds, and preservation of rare species. In addition to the CSDA, the GRCPT consists of GIS data layers identifying existing wildlife habitat and corridors, potential additional conservation sites for the protection of underrepresented rare species, and sub-watersheds and their integrity based on configuration of the surrounding land uses (The Nature Conservancy, University of Florida GeoPlan Center, and Archbold Biological Station, unpublished report).

Table 1. Smoke-sensitive area recommended minimum distances from conservation boundaries and their locations within the buffer zones of the Critical Smoke Dispersal Areas (CSDA).

Smoke-sensitive area		Minimum distance from conservation boundary	CSDA buffer zone(s) in which can be present
FDOT <sup>a</sup> Road Class	Description		
6	Minor arterial—rural	402 m (0.25 mi)	2, 3, and 4
8	Minor collector—rural	402 m (0.25 mi)	2, 3, and 4
9	Local—rural	402 m (0.25 mi)	2, 3, and 4
1	Principal arterial—interstate, rural	805 m (0.50 mi)	3 and 4
2	Principal arterial—other, rural	805 m (0.50 mi)	3 and 4
7	Major collector—rural	805 m (0.50 mi)	3 and 4
16	Minor arterial—urban	805 m (0.50 mi)	3 and 4
17	Collector—urban	805 m (0.50 mi)	3 and 4
19	Local—urban	805 m (0.50 mi)	3 and 4
11	Principal arterial—interstate, urban	1,609 m (1 mi)	4
	Principal arterial—freeways/ expressways, urban	1,609 m (1 mi)	4
14	Other principal arterial—urban	1,609 m (1 mi)	4
Other land uses			
	Residential/commercial/industrial	402 m (0.25 mi)	2, 3, and 4
	Hospitals/nursing homes	1,609 (1 mi)	4
	Aviation areas	3,220 m (2 mi)	Do not occur within CSDA

<sup>a</sup> FDOT, Florida Department of Transportation.

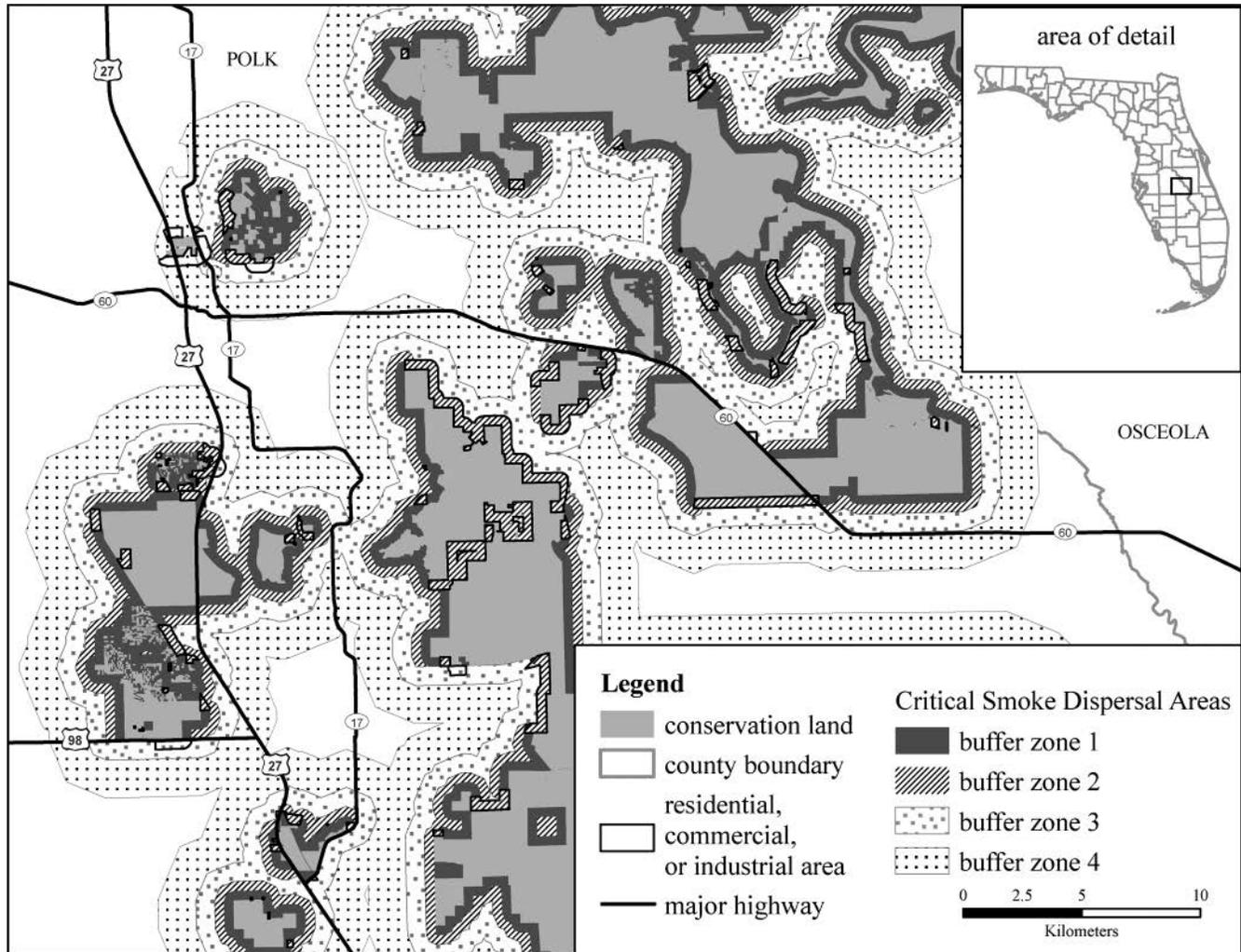


Figure 2. Detail of the four buffer zones of the Critical Smoke Dispersal Areas from southeastern Polk County, Florida, USA. The buffer zones are numbered 1 through 4, reflecting increasing suitability for development types of greater smoke sensitivity.

## SITE DESCRIPTION

The 66 conservation lands included in the CSDA data layer lie within 16.1 km (10 mi) of the Lake Wales Ridge (LWR) as delineated by Archbold Biological Station (Weekley et al. 2008). The LWR is the remnant of a Pleistocene shoreline in central peninsular Florida (Webb 1990). Extending from southern Lake and Orange counties to the southern end of Highlands County, the LWR averages 11.7 km (7.3 mi) wide and is 186.3 km (115.8 mi) long (Weekley et al. 2008). The LWR is a global hotspot of biological diversity (Turner et al. 2006), with at least 56 of the plant and animal species found on the LWR listed by the U.S. Fish and Wildlife Service as Threatened or Endangered or with a NatureServe ranking of G3 (globally vulnerable) or higher (Turner et al. 2006). The state of Florida began acquiring conservation land along the LWR and surrounding areas in 1992, and the LWR remains one of the state's highest priority acquisition areas (FDEP 2008).

The conservation lands within the CSDA comprise approximately 141,000 ha. These areas are a mosaic of xeric uplands (e.g., scrub and sandhill) embedded within a matrix

of mesic and hydric communities. Fire management is a critical strategy for these sites (TNC 2008). Fire return intervals for LWR natural communities range from 15–30 years for rosemary (*Ceratiola ericoides*) scrub (Menges 2007) to 1–8 years for pine (*Pinus* spp.) flatwoods (FNAI and FDNR 1990).

## METHODS

The CSDA GIS layer was developed in a series of four raster analyses using the Cost Weighted Distance Tool of the ArcGIS Spatial Analyst Extension. Cost-weighted distance mapping determines the least possible cost of traveling from a source (point of origin) to a given raster cell, calculated as the sum of values of raster cells that are passed through (ESRI 2004). For the CSDA analyses, the source was the conservation land boundary and the cost was the value of each raster cell reflecting the smoke sensitivity of the land cover type. Cost-weighted distance analysis requires two spatial data sets composed of raster images in GIS, one providing sources and one providing costs (ESRI 2004). All

rasters created for and resulting from the CSDA analysis had a 1-m resolution.

Land-use data sets were compiled from several sources. Commercial, residential, and industrial land uses within 0.402 km (0.25 mi) of conservation sites were visually identified and hand-digitized from the most recent digital orthophotos available for each county; refer to Table 2 for the scales of the digital photos used. GIS data layers for conservation sites, roads, aviation sites, hospitals, and nursing homes were obtained from various public and private agencies. The data sources are listed in Table 2. Road data were obtained from FDOT’s functional road class GIS shapefile. Functional class is related to traffic speed and density (FDOT 2003). Because the smoke sensitivity of a road is directly correlated with traffic speed and density, TNC utilized the FDOT road GIS data sets in mapping the CSDA.

After compiling data sets for all land uses and having land managers confirm the land-use configurations surrounding their sites, the land-use data were combined into a single shapefile that was then converted to a raster file to be used as the cost data set required for the analyses. Within the cost data set, each smoke-sensitive land use was given a value indicating the minimum buffer zone for that development type (Table 1). For example, a hospital was given a value of 4, representing buffer zone 4. All non-smoke-sensitive areas were given a default value of 1.

Table 2. GIS data layers utilized in the development of the Critical Smoke Dispersal Areas and their sources.

GIS data	Data source
Conservation lands	Florida Natural Areas Inventory–managed areas GIS shapefile ( <a href="http://www.fnai.org">www.fnai.org</a> [accessed 7 Feb 2010]); supplemented with site boundary information from Archbold Biological Station and The Nature Conservancy
Land uses within 0.25 mi	Polk County: 2007 digital orthophotos with 1-ft (0.30-m) resolution from county property appraiser
	Highlands County: 2008 digital orthophotos with 1-ft (0.30-m) resolution from county property appraiser
	Lake County: 2006 digital orthophotos with 1-ft (0.30-m) resolution from Lake County Geographic Information Services Division
	Osceola County: 2004 digital orthophotos with 1-m resolution from the South Florida Water Management District
	Orange County: 2004 digital orthophotos with 1-m resolution from the South Florida Water Management District
Hospitals and nursing homes	Florida Geographic Data Library ( <a href="http://www.fgdl.org">www.fgdl.org</a> [accessed 7 Feb 2010]) and land manager input
Aviation facilities	Florida Geographic Data Library ( <a href="http://www.fgdl.org">www.fgdl.org</a> ) and land manager input
Functional classification roadways feature class	Functional class road layer from Florida Department of Transportation

Four separate analyses were conducted, one for each buffer zone of the CSDA. Separate analyses were required because only developments occurring at less than the recommended minimum distance from the nearest conservation boundary were of concern. For example, a rural road does not incur a cost if it occurs beyond the recommended minimum distance of 402 m (0.25 mi) of a conservation boundary. The raster layer created in the previous analysis was used as the source file for the next analysis. The width of each buffer zone was determined by the distance traveled perpendicular to the conservation land boundary at which the cost exceeds the maximum width of that buffer zone type.

For the creation of the cost raster to be used in buffer zone 1, the ArcGIS Spatial Analyst Reclass Tool was used to reclassify all the smoke-sensitive land uses with a value of 402 (for 402 m); all other cells were given a value of 1 (for 1 m). The resulting file was used as the cost input, the conservation sites as the source, and 402 m as the maximum distance (i.e., the maximum width of the buffer zone). The reclassification resulted in the maximum cost being exceeded upon reaching any smoke-sensitive area, or else the maximum width of the buffer zone. Buffer zones 2, 3, and 4 were calculated separately in a similar manner, using the outside edge of the subordinate buffer zone as the source in each case. The width for each buffer zone was calculated by setting the appropriate maximum allowable cumulative cost for raster cells using the Cost Weighted Distance Tool and by specifying which classes of smoke-sensitive areas were considered. All four raster layers were combined into one raster file with values indicating the separate buffer zones (Figure 2).

## RESULTS AND DISCUSSION

The Critical Smoke Dispersal Areas data layer has facilitated TNC efforts to inform land-use planning within Polk and Highlands counties in Florida. TNC and Archbold Biological Station have engaged FDOT District 1, Highlands and Polk County planning departments, and the Central Florida Regional Planning Council in utilizing the CSDA within current planning frameworks.

FDOT has agreed to incorporate the Critical Smoke Dispersal data layer into the Efficient Transportation Decision Making (ETDM) for District 1. The ETDM is FDOT’s process for planning transportation projects, conducting environmental reviews, and permitting (FDOT 2002). The CSDA will be one of the data layers used to evaluate public safety and environmental concerns.

TNC, along with the Florida Division of Forestry, is working with the Polk County Planning Department and the Central Florida Regional Planning Council to develop the county’s Comprehensive Plan (T. Martin, TNC, personal communication). The current draft includes provisions for using the CSDA data layer along with the Division of Forestry’s Fire Risk Assessment Modeling in mapping Firewise protection areas, areas of wildfire hazard, and where fire is a critical management tool (T. Martin, TNC, personal communication).

Archbold Biological Station is currently utilizing the CSDA data layer in the development of the Highlands

County Corridor Design Project. The purpose of this project is to protect wildlife and smoke corridors in the county's Rural Area and Long Range Transportation Plans (R. Pickert, Archbold Biological Station, personal communication).

Encouraged by the receptiveness of the CSDA by local planning agencies, TNC is pursuing development of a statewide CSDA data layer with criteria to be reviewed and approved by fire management personnel at the state level.

TNC intends to update the CSDA data layer as new land-use information becomes available. As new aerial imagery becomes available for a county within the project area, new or expanded commercial, residential, and industrial areas will be digitized. Updated FDOT functional road class data, as well as GIS information for the other development types of concern, will be searched for on an annual basis at the minimum. When new information has been obtained, TNC will conduct a new CSDA analysis and submit the results to FDOT and the planning departments of Polk and Highlands counties.

## ACKNOWLEDGMENTS

I would like to thank Hilary Swain and Roberta Pickert of Archbold Biological Station; Tom Hocht of The University of Florida GeoPlan Center; and Tricia Martin, Steve Morrison, Adam Peterson, and Walt Thomson of The Nature Conservancy for their invaluable input and guidance throughout this project. This project was made possible through funding from the Lykes Family Endowment of the Florida Chapter of The Nature Conservancy.

## LITERATURE CITED

- ESRI. 2004. ArcGIS 9: using ArcGIS Spatial Analyst. ESRI, Redlands, CA.
- FDEP [Florida Department of Environmental Protection]. 2008. Florida Forever five year plan. Florida Department of Environmental Protection, Tallahassee.
- FDOT [Florida Department of Transportation]. 2002. Florida's EDTM process. Progress Report 2. Florida Department of Transportation, Tallahassee.
- FDOT [Florida Department of Transportation]. 2003. FHWA urban boundary and federal functional classification handbook. Florida Department of Transportation, Tallahassee.
- FNAI and FDNR [Florida Natural Areas Inventory and Florida Department of Natural Resources]. 1990. Guide to the natural communities of Florida. Florida Natural Areas Inventory, Tallahassee.
- Menges, E.S. 2007. Integrating demography and fire management: an example from Florida scrub. *Australian Journal of Botany* 55:261–272.
- TNC [The Nature Conservancy]. 2008. Lake Wales Ridge fire history database. The Nature Conservancy, Babson Park, FL.
- Turner, W.R., D.S. Wilcove, and H.M. Swain. 2006. State of the scrub: conservation progress, management responsibilities, and land acquisition priorities for imperiled species of Florida's Lake Wales Ridge. Archbold Biological Station, Lake Placid, FL.
- Webb, S.D. 1990. Historical biogeography. Pages 70–100 *in* R.L. Myers and J.J. Ewel (eds.). *Ecosystems of Florida*. University of Central Florida Press, Orlando.
- Weekley, C.W., E.S. Menges, and R.L. Pickert. 2008. An ecological map of Florida's Lake Wales Ridge: a new boundary delineation and an assessment of post-Columbian habitat loss. *Florida Scientist* 71:45–64.
- Zwick, P.D., and M.H. Carr. 2006. Florida 2060: a population distribution scenario for the State of Florida. Report to 1000 Friends of Florida, University of Florida GeoPlan Center, Gainesville.