

## **Base Map Updates Using GIS and Remote Sensing**

Authors: Mita Mathur, Kristin Brown, Larry Stipek

### **Summary**

*This paper presents an overview of the Base Map update project undertaken by the Loudoun County Office of Mapping and Geographic Information (OMAGI). OMAGI had for many years updated all base map data selectively according to development patterns, a process that resulted in a confusing mix of data. More recently, large contiguous areas of the county are updated from aerial photography through stereo compilation and photogrammetry. Ground features are captured and attributed through the county's base map maintenance services contract. Base map data layers include planimetric (buildings, roads, miscellaneous cultural features), environmental (hydrography, forest cover), and topographic (elevation contours and spot heights) features. Many annual cycles (2000 to present) of base map updates have contributed to the development of these layers that now include the development of an annual digital orthophoto.*

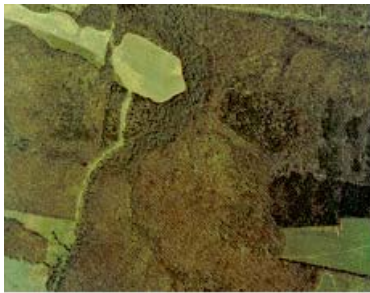
## Loudoun County – An Introduction

The County of Loudoun is approximately 520 square miles in size. Located within the Washington D.C. metropolitan area, the county is subject to intense development pressure. While the eastern portion of the county is developing rapidly, many western areas remain wooded and agricultural. In recent years, however, development has expanded into historically rural areas. The county's topography is also very diverse, ranging from relatively flat plains to the crest of the Blue Ridge Mountains.



Source: Loudoun County, Department of Economic Development

According to the 2006 Loudoun County Department of Economic Development Annual Growth Summary, "Over the past six years, the county led the Northern Virginia region with a population growth of 59 percent, accounting for 31 percent of Northern Virginia's population growth since 2000. Loudoun County has been one of the fastest growing counties in the US since the late 1990's. Projections show that Loudoun will be one of two counties in the region to continue to experience double-digit growth for each decade, 2010 through 2030." These images of the same place in eastern Loudoun document the rapid growth.



Aerial Image- 1978



Aerial Image- 2000



Aerial Image- 2007

The rapidly changing landscape has necessitated aggressive maintenance of many spatial data sets, particularly land records and the county's base map.

### **Loudoun County's GIS**

Loudoun County installed ESRI's ArcInfo in 1986, acquiring site license number 34. The county's GIS began as a standalone system and has developed over the decades into an enterprise system with over 100 corporate data layers and connections to nine other internal systems. The current system runs in ESRI'S ArcInfo 9.x in a Microsoft (MS) Windows networked environment. ArcGIS is served through MS Windows Terminal Servers with Citrix.

Data resides in the ESRI Geodatabase model on an IBM AIX UNIX server, using IBM's DB2 as the relational database, served through ESRI's Spatial Database Engine (SDE). The SDE Enterprise Geodatabase model was employed to standardize GIS operations and support business processes throughout the organization. Data are stored in the corporate ArcSDE geodatabase as a point, line or polygon feature class. The coordinate system is Virginia State Plane North Zone 4501, datum NAD83 HARN, vertical datum NAVD88, US Survey foot units.

The GIS is integrated with nine other systems, including E-911, and data maintenance to support them is critical. The land records feature dataset is maintained as a versioned geodatabase in SDE and is updated hourly. Parcel boundaries are created and parcel identification numbers are generated using ArcGIS. These identifiers, together with address data and tables derived from several other spatial data sets, are transferred to the county's Land Management Information System (LMIS). LMIS provides a wide range of land related data, including GIS and assessment information to users in tabular format. LMIS is used to manage building, zoning and health permits, inspections, and many other functions.

The public accesses maps and spatial data through a web service and at a public information counter. The Office of Mapping and Geographic Information maintains a public information counter that uses an ArcGIS application to create map products for the general

public and for staff. These maps use standardized symbology and formatting for a consistent product based on users' requests.

WebLogis, the county's web mapping application, is used extensively in-house by staff for quick and easy access to GIS data. The application is accessible to the public on the internet as well. Intranet and internet data are updated nightly. The WebLogis application is linked to the assessment database giving users the ability to move between the two systems easily. The service includes multiple base map layers.

The GIS is a distributed system with approximately 300 internal users many of whom are also data maintainers. Various departments are dependent on the county's base map data to reference their data layers and to produce their own maps and analyses.

## **Loudoun County Base Map Maintenance**

Base map typically refers to a representation of geographic features that are visible on the ground in an aerial image. They provide the foundation or reference upon which other data layers can be developed or mapped, and are the foundation of the county's geographic information system.

The county's base map and most of the other corporate spatial data were developed and are maintained at a scale of 1:2400. The base map is a conventional photogrammetric product that is partially maintained annually from aerial photography.

The original base map was developed from aerial photography between 1978 and 1985. Approximately one third of the map was produced in digital format, and the rest of the scribe-coats were scanned in the early 90's. The map has always been maintained, though updates focused on developing areas and neglected areas of less growth.

The county has conventional, film-based, unrectified, black and white photographs, flown at a scale of 1:12,000, for the entire county for most years since 1978. This has been the traditional source for base map updates for many years. Additionally, U.S. Department of Agriculture aerial images from 1957 were scanned in 2006 and orthorectified in-house. 1937 images have been ordered from the National Archives. Refer to Appendix 1 for aerial index.

As part of the base map update process, digital orthophotos have been produced since 2002 and are available to GIS users as an added resource. Orthophotos are completely rectified copies of original photographs. Apart from planning and decision making purposes, county staff uses orthophotographs as a background display for other feature layers. It provides the map user with confidence that map layers are spatially aligned and represent real objects. ESRI'S ArcGIS Desktop application has provided the county with a solution for storing, managing, updating, accessing, analyzing, and distributing orthophotos. ArcSDE, a core component of ESRI's raster data management system, has enabled the county to store the raster data for fast, online, multiuser access.

Digital Orthos are available in these formats:

- Uncompressed GeoTIFF covering 5000' x 5000' tiles each.
- Compressed MrSID covering 5000' x 5000' tiles each.
- Single compressed MrSID comprising entire countywide extent- seamless image covering a spatially continuous area.
- Single geotiff comprising entire countywide extent available on SDE for fast, online, multiuser access across various departments. Metadata for the orthos is stored in SDE and applies to complete dataset.

Loudoun County Office of Mapping and Geographic Information, Public Information Counter has countywide Panchromatic and color digital orthophotos for the last several years. Refer to the table below for details:

Year	Resolution	Coverage	Type
2002	1 foot	Countywide	Color
2004	1 foot	Eastern Loudoun	Black and White
2005	1 foot	Countywide	Black and White
2006	1 foot	Countywide	Color
2007	1 foot	Countywide	Black and White

The color imagery was obtained from the Virginia Geographic Information Network.

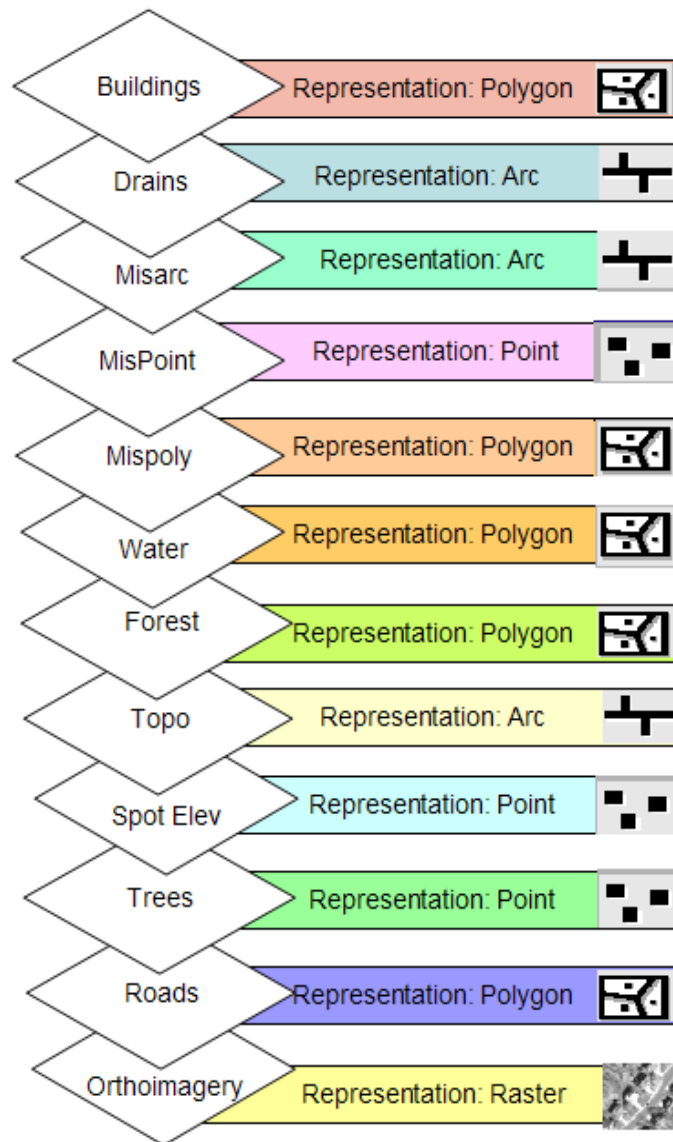
Refer to Appendix 2 for Loudoun County ortho index.

After years of selective updates based upon development patterns, the county had an eastern, suburban part of the county that got updated almost yearly, and a western, rural part of the county that changed only a little each year but fairly significantly over a longer period. The confusing patchwork of planimetric data and the obsolescence of the data in rural areas lead to the decision to remap the county. The strategy now is to do updates for the 1/3<sup>rd</sup> of the county each year to make sure the whole county is updated at least every three years. For more details refer to base map update phases and years in Appendix 3 and 4.

A complete, countywide remapping project, conducted in two phases, yielded the current data set. Phase I, using 2002 Virginia Base Mapping Program (VBMP) digital scanned imagery, and Phase II, using 2004 scanned aerial photography comprises the initial re-map effort. The initial project was completed in 2005 and now undergoes annual updates. The first annual update, Phase III, was derived from 2005 imagery and completed in fall of 2006. The second annual update, Phase IV, was derived from 2007 imagery and completed in spring of 2007. Phase 5 of the base map updates is underway and is expected to be completed by October 2008.

The content of the base map has changed little since it was first developed. Since it is a conventional photogrammetric product, the map includes features that are visible from the air that can be compiled from 1:12000 photography at 1:2400. The features are buildings, drainage, water bodies, forestry, tree points, road pavement and driveways, topography, spot elevations, miscellaneous polygons (recreational fields, swimming pools, quarries, and golf course features, etc), miscellaneous points (manholes, poles, hydrants and towers, etc.) and miscellaneous arcs (sidewalks, culverts, bridges, trails, fences etc.).

The diagram below describes the various base map layers that are maintained by OMAGI (The Office of Mapping and Geographic Information) and are used in various analyses, planning and in decision making.

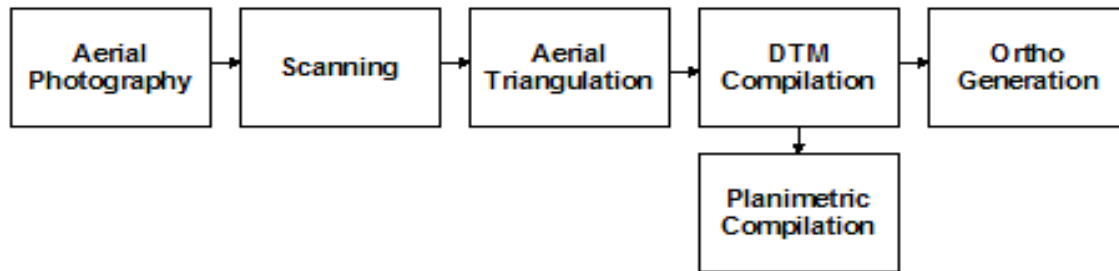


**Thematic Layers of the Base Map Data Model**

Planimetric mapping for the base map is accomplished in a soft copy stereo environment which is the most efficient, comprehensive, and accurate technique today. By utilizing the new aerial photography, planimetric features are updated in a 3-D softcopy stereo environment. Experienced compilers use the images to collect and classify the data. After compilation, data are exported to an ArcGIS geodatabase feature class. All of these layers are constructed to fit together, so that in a given area features such as roads, rivers and ponds, trees, etc, can be viewed one atop the other, and will all appear in the correct locations relative to one another. Base map data layers have features that typically fit into one of three general types-polygon, line, or point. Because base map data is organized into themes, and because these layers align with each other, users can see how features in these themes relate to or interact with each other.

## Methodology and Time Frame

The flow diagram below is a generalized workflow for the base map update project.



Loudoun county is flown annually, currently using conventional film based cameras, in March of each year. Thereafter, these aerial images are scanned for the annual ortho generation and base map updates. Aerial Triangulation is performed using ground control points and Airborne Global Positioning system (ABGPS). A DTM is compiled for ortho generation and for planimetric and topography compilation. The typical annual timeline for Loudoun County base map maintenance project is:

Pre-March – Determination of control points, if necessary

March – Aerial mission

April- Photo scans

May – Aerial Triangulation

June – DTM Update

July – Ortho generation

August – October – Base map updates

October through December –Merge with corporate data and release the layers for public use.

## Quality Assurance /Quality Control

The Quality Assurance Quality Control Plan sets expectations for data quality standards, and describes methods and procedures for measuring data against those standards. Quality control procedures are organized to make the best use of time, tools, and people. The QA/QC methodology and supporting tools include ArcGIS based automated batch processing to check for incompatible schemas, topologies, and logical inconsistencies between attribute values, as well as visual inspection tools to log missing and incorrectly attributed features. County's staff is trained on the QA/QC procedures and tools to perform QA/QC services on the base map data.

## Data Accuracy

Accuracy Assessments have been computed according to The National Standard for Spatial Data Accuracy (NSSDA). NSSDA implements a statistical and testing methodology for estimating the positional accuracy of points on maps and in digital geospatial data with respect to georeferenced ground positions of higher accuracy.

Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value.



All base map data has been tested and meets NSSDA and ASPRS accuracy requirements for 1:2400 scale maps.

## **Metadata**

Metadata is available for all the base map layers. The county provides metadata in three formats- HTML, XML and TXT. FGDC compliant metadata is developed using ArcGIS desktop applications. ArcCatalog, a component of ArcGIS, automatically captures core metadata and updates metadata automatically. Using ArcCatalog, metadata is created in XML format and is exported to Text and HTML. To access metadata from loudoun.gov:

Click on **"Department List"** link at the right in table of contents  
Navigate and click on **"Mapping and Geographic Information"** link  
Click on **"OMAGI Documents and Information"**  
Click on **"Metadata"** folder  
SDE NAD83 Metadata folder contains current base map metadata.

## **Conclusion**

Loudoun county, VA has a seamless countywide base map geodatabase. The base map is important to Loudoun as it is used as a reference when mapping all other data. Data sets like parcels, addresses, street centerline, zoning, and planning districts often rely on base map delineations. The base map update is an ongoing project which entails maintenance and update of the GIS base map layers including buildings and roads, cultural features, hydrography and forest cover, contours and spot elevations. The GIS base map is distributed to county GIS users on an annual basis. Base map data are stored at a central, secure location in SDE and can be assessed in various ways across many county departments and by the public. Analysts, planners and decision makers use base map data to discover and demonstrate spatial relationships, making the base map a valuable tool to explore management and policy alternatives. The base map is a critical data set that must be regularly maintained. Updating large, contiguous areas has resulted in consistent and timely data for E-911, AVL, and other applications.

## References

Federal Geographic Data Committee, Geospatial Positioning Accuracy standards, Part 3: National Standard for Spatial Data Accuracy (NSSDA), 1998

Federal Geographic Data Committee, FGDC-STD-001-1998, Content Standard for digital geospatial metadata (revised June 1998). FGDC, Washington. DC

ESRI, Metadata and GIS, An ESRI White Paper, October 2002

ESRI, Topographic Base Map Data Model Poster, February 2003

## **Acknowledgement**

The authors would like to thank Infotech Enterprises America, AirPhotographics, L Robert & Kimball Associates for their assistance in making this paper possible.

The authors would like to thank the following Loudoun county employees for their assistance: David Ward, Water Resources Engineer; Doug Gibson, GIS Specialist; Stephen Zlato, GIS Specialist; Chris Thomas, GIS Specialist; Adam Diehl, GIS Analyst; David Torroca, GIS Manager.

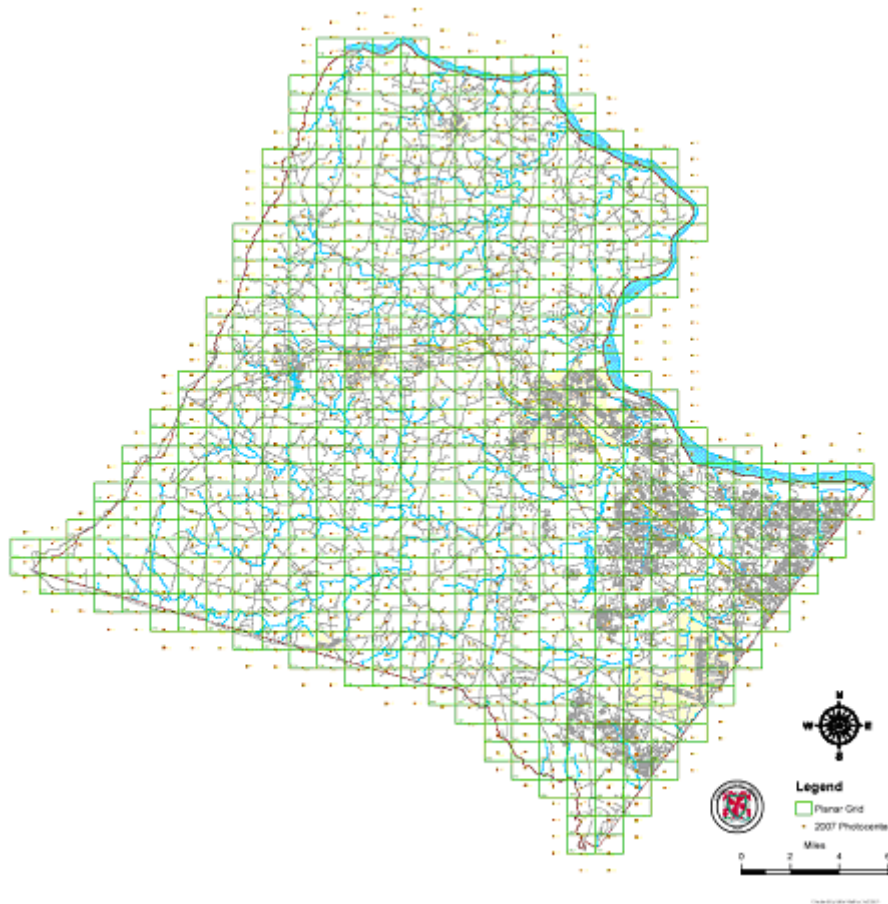
## **Author Information**

Mita Mathur  
Contract Manager/ GIS Analyst  
Office of Mapping and Geographic Information  
1 Harrison St., MS # 65  
Leesburg, VA 20175  
703-737-8768  
703-771-5075 (fax)  
[mmathur@loudoun.gov](mailto:mmathur@loudoun.gov)

Kristin Brown  
Manager, Development and Analysis Division  
Office of Mapping and Geographic Information  
1 Harrison St., MS # 65  
Leesburg, VA 20175  
703-777-0166  
703-771-5075 (fax)  
[kbrown@loudoun.gov](mailto:kbrown@loudoun.gov)

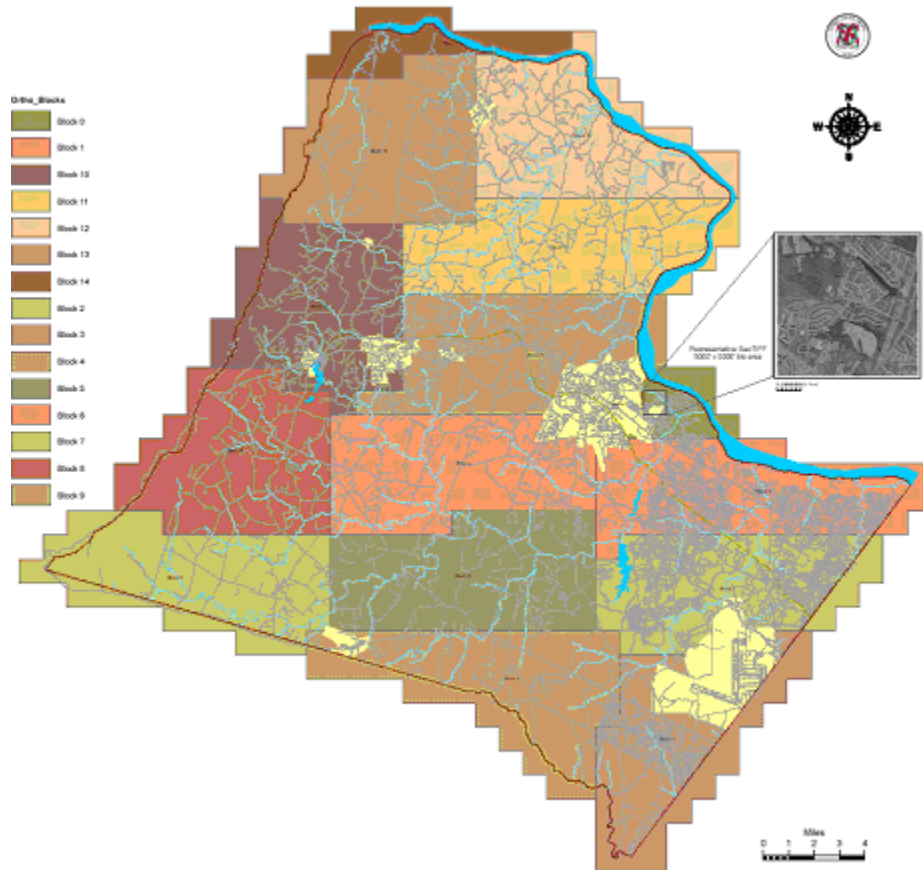
Larry Stipek  
Director  
Office of Mapping and Geographic Information  
1 Harrison St., MS # 65  
Leesburg, VA 20175  
703-771-5778  
703-771-5075 (fax)  
[lstipek@loudoun.gov](mailto:lstipek@loudoun.gov)

**Loudoun County, VA, Aerial Photography Index- 2008**



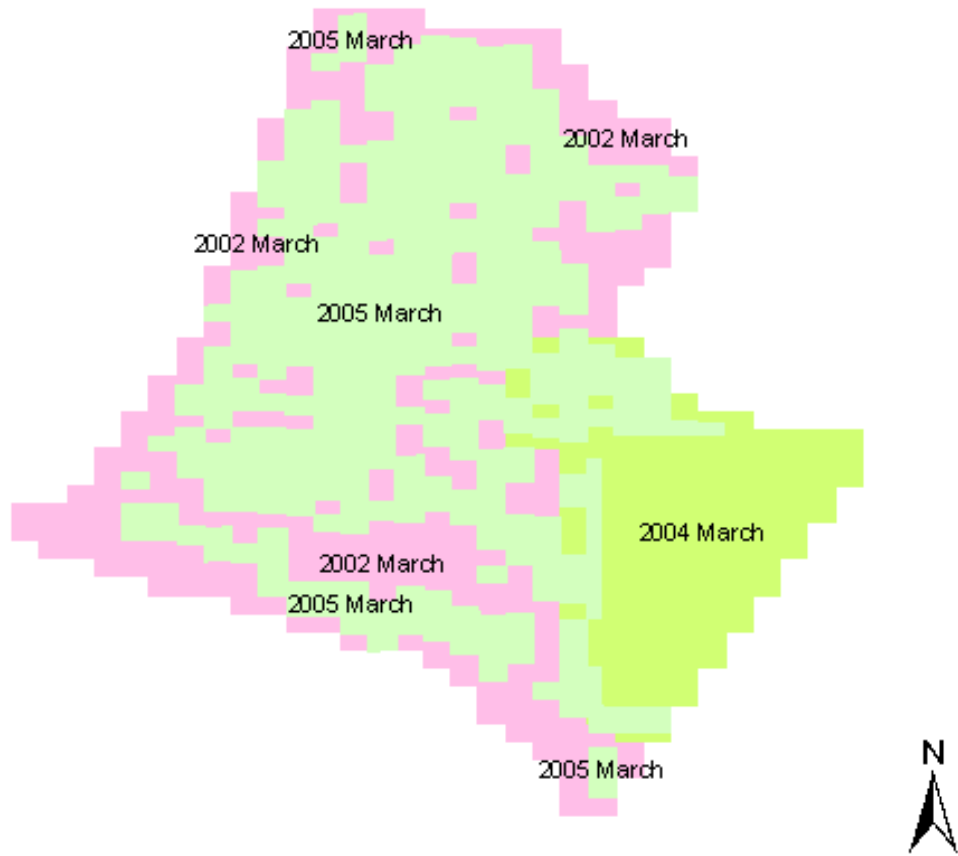
Note: To access detailed and recent map of Aerial Photography Index from [www.loudoun.gov](http://www.loudoun.gov)  
Click on **"Department List"** link at the right in table of contents  
Navigate and click on **"Mapping and Geographic Information"** link  
Click on **"OMAGI Documents and Information"**  
Click on **"Basemap"** folder

### Loudoun County, VA, Digital Ortho Index- 2008






Note: To access detailed and recent map of Ortho Index from [www.loudoun.gov](http://www.loudoun.gov)  
Click on "**Department List**" link at the right in table of contents  
Navigate and click on "**Mapping and Geographic Information**" link  
Click on "**OMAGI Documents and Information**"  
Click on "**Basemap**" folder

### Loudoun County Base Map Maintenance Cycle- 2002-2005

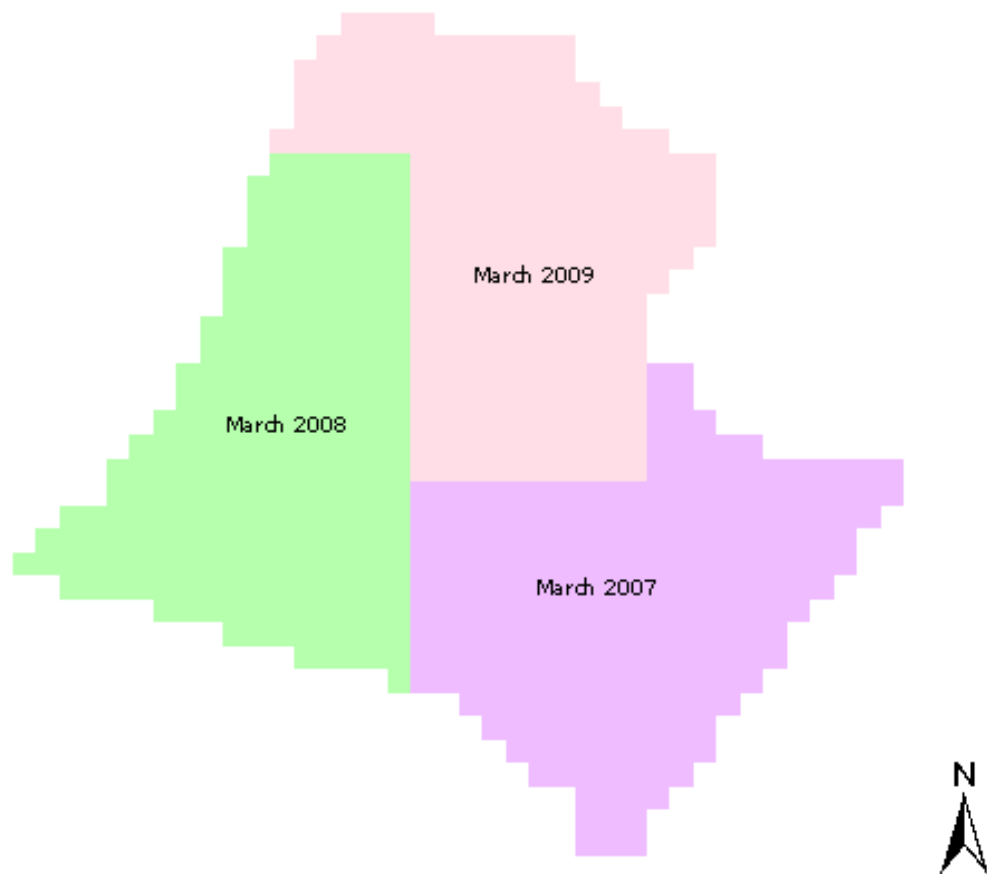


#### Update Phase No




-  Phase 1, 2002
-  Phase 2, 2004
-  Phase 3, 2005

Note: To access detailed and recent map of Base Map Updates from [www.loudoun.gov](http://www.loudoun.gov)  
Click on "**Department List**" link at the right in table of contents  
Navigate and click on "**Mapping and Geographic Information**" link  
Click on "**OMAGI Documents and Information**"  
Click on "**Basemap**" folder

### Loudoun County Base Map Maintenance Cycle- 2007-2009



#### Proposed Cycles

-  Phase 4, 2007
-  Phase 5, 2008
-  Phase 6, 2009

Note: To access detailed and recent map of Base Map Updates from [www.loudoun.gov](http://www.loudoun.gov)  
Click on "**Department List**" link at the right in table of contents  
Navigate and click on "**Mapping and Geographic Information**" link  
Click on "**OMAGI Documents and Information**"  
Click on "**Basemap**" folder