High Resolution Land Cover Data in the Chesapeake Bay Watershed

The Chesapeake Conservancy is pioneering the broad-scale application of emerging technologies and available high resolution aerial imagery and elevation data to develop new land cover datasets that are increasing the effectiveness and efficiency of conservation and restoration practices in the Chesapeake Bay watershed.

Accurate land use and land cover (LULC) information is one of the most important spatial datasets needed for environmental management in the Chesapeake Bay watershed. Used for everything from ecological habitat mapping to tracking development trends, LULC data play a central part of the Chesapeake Bay Program (CBP) partnership's modeling and management efforts. Existing LULC datasets, such as the National Land Cover Dataset (NLCD), have proven extremely useful in identifying priority watersheds in need of conservation and restoration, however these data often lack the resolution needed to track fine-scale trends in land conversion or make field-scale decisions about where to focus efforts to maximize water quality benefits while protecting critical habitats.

Recognizing the importance of datasets that are relevant at the local scale, a small number of initiatives have been undertaken to produce high resolution information for individual counties or jurisdictions. While important for local decision making, discrepancies in classification schemes, accuracy, and data resolution, as well as a lack of high resolution data for the majority of the watershed, make it difficult for the CBP Partners to incorporate these data into the suite of Partnership models to be used in supporting decision making in the 2017 Mid-Point Assessment of the Chesapeake Bay TMDL. CBP Staff have indicated that a high resolution land cover dataset would benefit all of the Partnership's Goal Implementation Teams and have direct benefits for almost all of the outcomes specified in the 2014 Chesapeake Bay Watershed Agreement- particularly the vital habitats, water quality, healthy watersheds, and land conservation outcomes.

To help provide the CBP federal, state, and local partners with the level of detail needed, the Chesapeake Conservancy is proposing a project to produce a consistent high resolution, extremely accurate land cover dataset for all of the counties that comprise the Chesapeake Bay watershed (Figure 1). Using publicly available aerial imagery from the USDA's National Agriculture Imagery Program (NAIP) (Figure 2) and LiDAR elevation data from states and the USGS (Figure 3), the Conservancy has created a scalable and replicable methodology to generate land classification datasets with a resolution of 1 meter and an overall accuracy that is close to 95% (Figure 4).

Methodology

Chesapeake Conservancy has developed a multi-step image classification workflow that combines an object-oriented rule-based feature extraction with a secondary manual reclassification quality check. The workflow starts by creating a mosaic dataset from a collection of 1 meter resolution 4-band aerial imagery collected by the USDA's National Aerial Imagery Program. Simultaneously, two additional mosaic datasets are created of digital elevation model (DEM) data and a LiDAR point cloud, both provided by the USGS. Using the footprint of the NAIP imagery tiles, an iterative process creates complimentary digital surface model (DSM) and canopy/ structure height layers from the LiDAR and DEM datasets to be used as ancillary data in the feature extraction.

Using a proprietary rule set, each tile of aerial imagery will be segmented and classified into eight classes:

- Water
- Tree canopy
- Scrub-shrub
- Herbaceous/Grass
- Barren
- Impervious surfaces- Roads/Other†

† Impervious surfaces will also be derived from leaf-off imagery to enhance feature accuracy

- Impervious surfaces- structures*†
- Impervious surfaces- obscured by tree canopy**†

After the initial classification has been completed for a tile, a manual reclassification will be used to improve the overall accuracy and eliminate the majority of misclassified landscapes.

Simultaneously, Chesapeake Conservancy will use sub-meter resolution leaf-off aerial imagery collected by the watershed states from 2011-2013 to segment and extract impervious surfaces with a greater accuracy. The Conservancy will then overlay the leaf-off impervious surface data with the leaf-on classification to map the three impervious surface classes detailed above.

LiDAR point-cloud data exists for about 75% of the Chesapeake Bay Watershed, with some gaps in New York, Virginia, and West Virginia (Figure 3). In areas where LiDAR data do not exist, Chesapeake Conservancy still has the ability to produce high-resolution land cover data with similar accuracy levels using recently announced aerial imagery, produced by Leica Geosystems and ESRI, that will be available watershed-wide by the end of 2015. Originally collected to produce the NAIP imagery product, these high resolution data includes a fifth band that contains surface elevations and can be substituted for a DSM produced by a LIDAR point cloud for our classification purposes. While there is a cost associated with this data, approximately $\$3/mi^2$, it is minimal and will only be focused on counties where LIDAR data has not been collected.

Intended Accuracy

Based on conversations with Chesapeake Bay Program's Land Use Working Group and USGS staff on the Chesapeake Bay Program Office's Land Team, the resulting land cover classification datasets will have:

- An overall accuracy of approximately 95%
- An in-class accuracy for impervious surfaces and tree canopy classes above 95%, and
- A minimum accuracy for any given class of at least 90%.

Partnership with other organizations

When possible, Chesapeake Conservancy will partner with other organizations producing high resolution land cover products within the Chesapeake Bay watershed to ensure compatibility and to reduce duplication of effort. Chesapeake Conservancy is currently discussing a potential partnership with the University of Vermont's Spatial Analysis Laboratory, which is currently contracted by the United States Forest Service to produce high resolution forest canopy data in portions of the watershed. If a cost-sharing partnership can be established in these areas, UVM will act as a sub-contractor to Chesapeake Conservancy. Chesapeake Conservancy will ultimately be responsible for the output meeting the accuracy criteria set forth above and for the integration and delivery of UVM's data into a consistent dataset for the Chesapeake Bay watershed.

Given the Commonwealth of Virginia has indicated that it will pursue statewide land cover data independent from this proposal, Chesapeake Conservancy will also work with the Virginia Geographic Information Network (VGIN) to ensure the intended accuracy and eight classes of land cover data are fully consistent with VGIN's work being conducted in parallel to acquire land cover data for all of Virginia.

† Impervious surfaces will also be derived from leaf-off imagery to enhance feature accuracy

* Impervious structures will be separated from other impervious surfaces using the LiDAR point cloud

** Impervious surfaces obscured by tree canopy will be delineated by comparing leaf-on and leaf-off impervious surface classifications and are intended to be used as a "swing" class that can be used for both tree canopy and impervious surface calculations

Deliverables

There will be three primary deliverables produced through the proposed project:

1. A 1m resolution, 8 class, land cover dataset, with complete coverage for all counties that intersect the Chesapeake Bay watershed in New York, Pennsylvania, Maryland, Delaware, West Virginia, and the District of Columbia.

2. This data will be delivered to the Partnership as a seamless dataset covering the entire project area as well as separated individually by county to make it more accessible to local and state partners.

3. Accuracy assessments for each county in the project area that describe the overall and in-class accuracy. The accuracy of land cover will be assessed through the visual interpretation of aerial imagery using a stratified random sampling design (stratified by county and class) with a variable point density based on the heterogeneity of the land cover.

4. Mosaic datasets of the source imagery, DEM data, DSM data derived from the LiDAR point cloud, and canopy/structure height layer used in the classification process. Each data product will be provided to the Partnership as a mosaic dataset composed of the individual tiles processed to the extent of the NAIP imagery footprints.

5. Documentation of the methodologies followed in each step—e.g., data acquisition, processing, quality assurance, and accuracy confirmations—followed in the generation of the resultant land cover dataset.

Proposed Timeline

It is anticipated that the data will be delivered within fourteen months of the start date with an absolute deadline of May 31st, 2016.

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Collection of Source Imagery and Elevation Data														
Processing DEM, DSM, and Canopy /Structure Height Data														
Processing Initial Land Cover Classification														
Manual Reclassification														
Final QA/QC														
Accuracy Assessments														
Deliver Data to Chesapeake Bay Program														

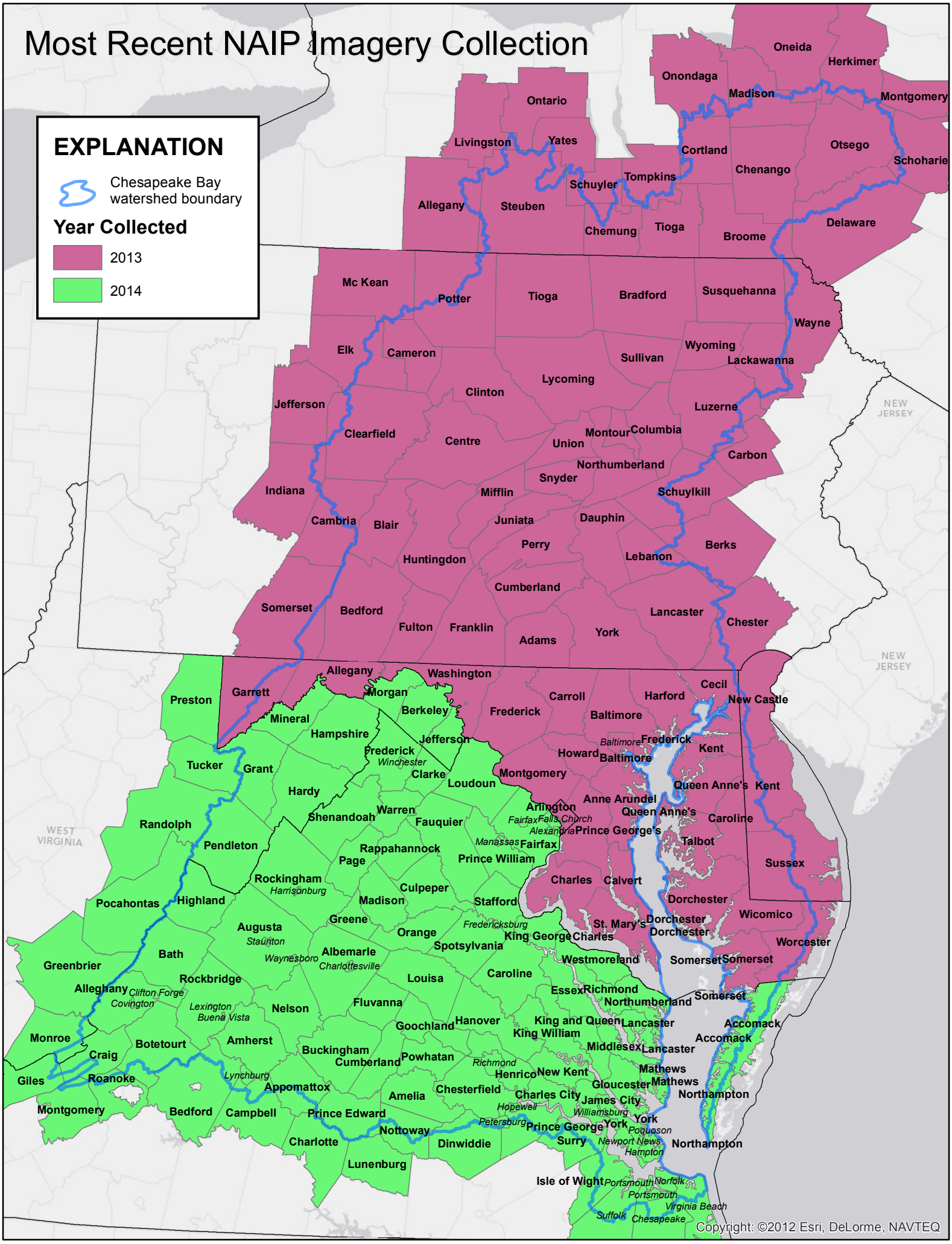
If a partnership with UVM's Spatial Analysis Lab is reached, the amount of time required to process the land cover classification will be condensed and re-evaluated as there will effectively be two teams working on the classification simultaneously.

Progress updates will be provided to the CBP's Land Use Workgroup and the Water Quality Goal Implementation Team quarterly and a "live" web-based progress map will be updated weekly to provide the Partnership with an up-to-date status of the project on demand.

Chesapeake Conservancy
Proposed High Resolution Land Cover Budget

		2015 (10 months)	2016 (6 months)	Project Total
PERSONNEL				
Salaries				
	Dir. of Conservation Innovation	$ 20,625.00	$ 12,375.00	*$ 33,000.00*
	Conservation Manager	$ 17,875.00	$ 10,725.00	*$ 28,600.00*
	Conservation Analyst II	$ 13,200.00	$ 7,920.00	*$ 21,120.00*
	Project Manager	$ 54,166.67	$ 32,500.00	*$ 86,666.67*
	Conservation Analyst #1	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #2	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #3	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #4	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #5	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #6	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #7	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Conservation Analyst #8	$ 39,583.33	$ 23,750.00	*$ 63,333.33*
	Administrative Manager	$ 5,200.00	$ 3,120.00	*$ 8,320.00*
	Executive Director	$ 4,500.00	$ 2,700.00	*$ 7,200.00*
	Subtotal Salaries	$ 432,233.33	$ 259,340.00	*$ 691,573.33*
	Payroll taxes and fringe benefits	$ 99,413.67	$ 59,648.20	*$ 159,061.87*
	Total Personnel Direct	**$ 531,647.00**	**$ 318,988.20**	***$ 850,635.20***
NON-PERSONNEL				
Travel				
	Travel Mileage ($0.565/mi)	$ 1,000.00	$ 1,000.00	*$ 2,000.00*
	Travel Lodging ($125/night)	$ 2,500.00	$ 2,500.00	*$ 5,000.00*
Equipment				
	9 workstations ($3500 each)	$ 31,500.00		*$ 31,500.00*
	Server	$ 15,000.00		*$ 15,000.00*
	Office Equipment	$ 9,000.00		*$ 9,000.00*
Supplies				
	12 ArcGIS Licenses ($108/ea)	$ 1,296.00	$ 1,296.00	*$ 2,592.00*
	10 ENVI Licenses ($500/ea)	$ 5,000.00	$ 5,000.00	*$ 10,000.00*
Contractual				
	IT Support	$ 3,500.00	$ 2,100.00	*$ 5,600.00*
	Leica Imagery ($3/mi^2)		$ 20,000.00	*$ 20,000.00*
Other :				
	Rent	$ 36,000.00	$ 24,500.00	*$ 60,500.00*
	Total Non-Personnel Direct	**$ 104,796.00**	**$ 56,396.00**	***$ 161,192.00***
TOTAL DIRECT COSTS		**$ 636,443.00**	**$ 375,384.20**	***$ 1,011,827.20***
Indirect Cost		$ 190,932.90	$ 112,615.26	*$ 303,548.16*
TOTAL EXPENSES		**$ 827,375.90**	**$ 487,999.46**	***$ 1,315,375.36***

Counties in the Chesapeake Bay Watershed


Most Recent NAIP Imagery Collection
EXPLANATION
Chesapeake Bay watershed boundary
Year Collected
2013
2014
Oneida
Herkimer
Onondaga
Madison
Montgomery
Ontario
Livingston
Yates
Cortland
Otsego
Schoharie
Chenango
Tompkins
Schuyler
Allegany
Steuben
Chemung
Tioga
Broome
Delaware
Mc Kean
Potter
Tioga
Bradford
Susquehanna
Wayne
Elk
Cameron
Sullivan
Wyoming
Lackawanna
Lycoming
Clinton
Jefferson
Luzerne
Clearfield
Centre
Union
Montour
Columbia
Carbon
Northumberland
Snyder
Indiana
Mifflin
Schuylkill
Cambria
Blair
Juniata
Dauphin
Perry
Berks
Lebanon
Huntingdon
Cumberland
Somerset
Bedford
Fulton
Franklin
Adams
York
Lancaster
Chester
NEW JERSEY
Allegany
Washington
Garrett
Morgan
Preston
Berkeley
Carroll
Harford
Cecil
New Castle
Mineral
Frederick
Baltimore
Hampshire
Jefferson
Baltimore
Frederick
Howard
Kent
Frederick
Winchester
Tucker
Grant
Clarke
Montgomery
Loudoun
Queen Anne's
Kent
Hardy
Anne Arundel
Arlington
Warren
Queen Anne's
Caroline
Shenandoah
Fauquier
Fairfax
Falls Church
Alexandria
Prince George's
Randolph
Talbot
Manassas
Fairfax
Pendleton
Rappahannock
Page
Prince William
Sussex
Rockingham
Harrisonburg
Charles
Calvert
Culpeper
Pocahontas
Highland
Madison
Stafford
Dorchester
Wicomico
Greene
Fredericksburg
St. Mary's
Dorchester
Augusta
Staunton
Orange
King George
Charles
Worcester
Spotsylvania
Bath
Albemarle
Waynesboro
Charlottesville
Westmoreland
Somerset
Somerset
Greenbrier
Caroline
Louisa
Rockbridge
Essex
Richmond
Alleghany
Clifton Forge
Covington
Northumberland
Somerset
Lexington
Buena Vista
Nelson
Fluvanna
Goochland
Hanover
King and Queen
Lancaster
Accomack
Monroe
King William
Accomack
Botetourt
Amherst
Middlesex
Lancaster
Craig
Buckingham
Cumberland
Powhatan
Richmond
Mathews
Giles
Roanoke
Lynchburg
Henrico
New Kent
Gloucester
Mathews
Appomattox
Chesterfield
Charles City
James City
Northampton
Amelia
Hopewell
Williamsburg
Montgomery
Bedford
Campbell
Prince Edward
Petersburg
York
Nottoway
Prince George
Poquoson
Charlotte
Dinwiddie
Surry
Newport News
Northampton
Hampton
Lunenburg
Isle of Wight
Portsmouth
Norfolk
Portsmouth
Virginia Beach
Suffolk
Chesapeake
WEST VIRGINIA
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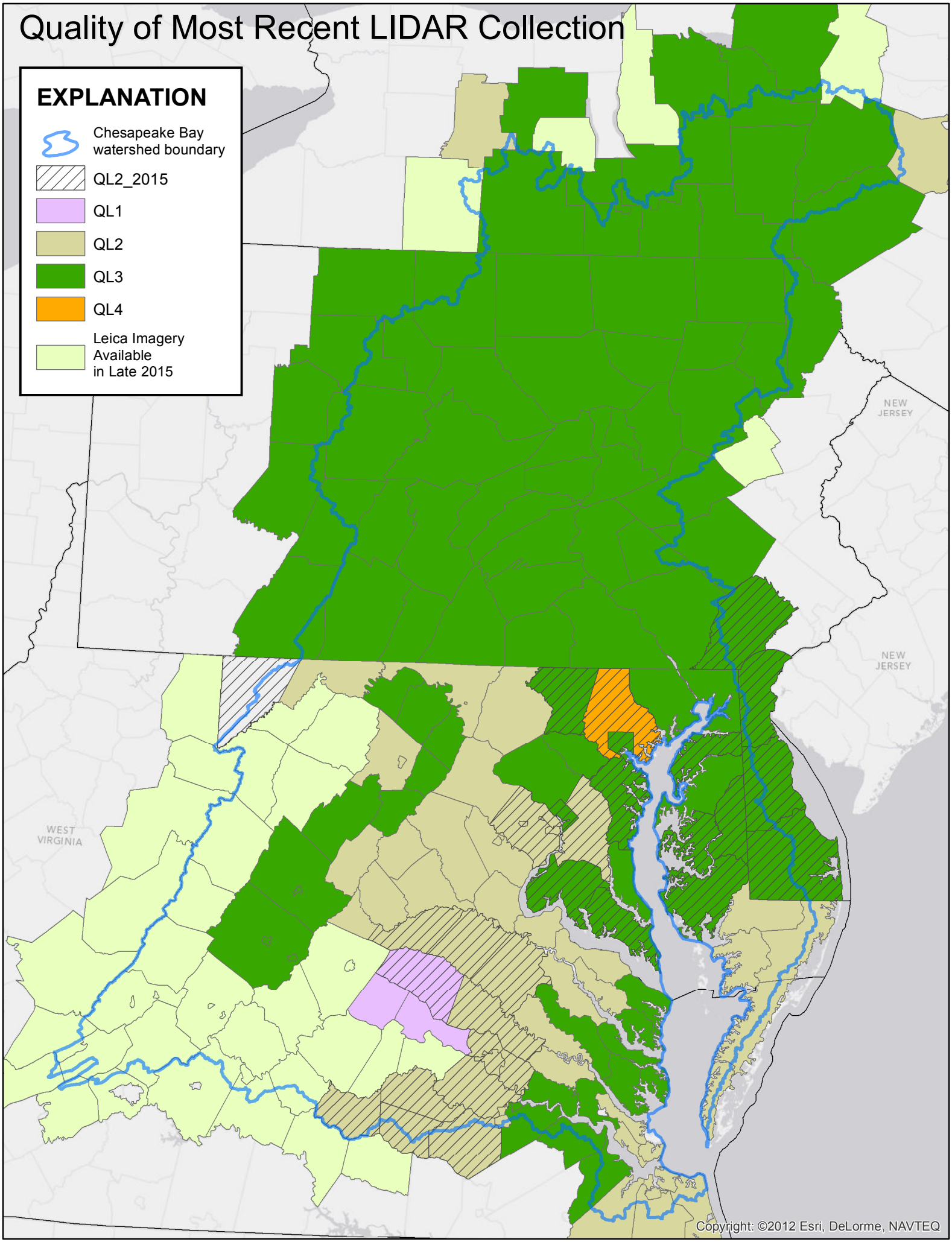
Quality of Most Recent LIDAR Collection



Accuracy of Existing Conservancy High Resolution Datasets