Quality Assurance Project Plan
for
Long-term Land Cover/Land Use Monitoring Program Development and Implementation

Prepared by
Chesapeake Conservancy
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Prepared for
Region 3 EPA Office
1650 Arch St, Philadelphia, PA 19103

Revision #1
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Approvals Signature (required prior to project start):

____________________________________ Date: ____________________
EPA Project Manager/Officer

____________________________________ Date: ____________________
EPA QA Manager/Representative

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1.0 PROJECT MANAGEMENT

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1.3 Distribution List (EPA QA/R-5 A3)

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<u>1.4 Project Organization</u> (EPA QA/R-5 A4)

Chesapeake Conservancy (Conservancy) is a non-profit organization based in Annapolis, MD. The Conservancy's mission is to conserve and restore the natural and cultural resources of the Chesapeake Bay watershed for the enjoyment, education, and inspiration of this and future generations. To help accomplish this mission, the Conservancy has established the Conservation Innovation Center (CIC) to develop partnerships, products, and processes that will allow stakeholders to maximize the efficiency and effectiveness of their conservation and restoration efforts. Through the CIC, the Conservancy is creating partnerships with colleges and universities throughout the United States to leverage cutting-edge research and make it accessible for restoration professionals. Staff are researching and advancing new methods of identifying high-priority landscapes that provide the optimal locations for conservation and restoration action. In addition, the team is leveraging the latest technologies and mobile platforms to democratize data and enable everyone to access the best available information. By learning from other industries, the CIC is able to adapt the most promising tools and techniques to advance both our mission and the environmental movement as a whole.

The Conservancy will receive training in the context of tasks and functions related to data quality requirements by Chesapeake Bay Program and the EPA. In addition, Conservancy staff will draw upon their educational background, experience, professional symposia, and on-the-job training. Staff participates in technical workshops to share and expand their knowledge in their areas of expertise. Staff proficiency is demonstrated through workshop presentations, written reports, committee presentations, and Conservancy publications. The Conservancy's Director of Conservation Technology, Geospatial Program Manager, and Controller will complete all necessary EPA Quality Assurance Classes.

For Objective 1, the Conservancy will work with the University of Vermont Spatial Analysis Laboratory (UVM), an applied research facility located in the Rubenstein School of Environment & Natural Resources (RSENR). Expertise includes ecosystem assessments, biodiversity analysis, land cover mapping, conserved lands planning, scenario modeling, LiDAR processing, web-based mapping, and transportation analysis. UVM's collaborators include consulting firms, non-profits, government agencies, municipalities, national labs, and other units at UVM, including; the United States Department of Agriculture (USDA) Forest Service Northeastern Research Station, Transportation Research Center, Gund Institute for Ecological Economics, and the Geography Department.

The Conservancy will receive training in the context of tasks and functions related to data quality requirements by Chesapeake Bay Program (CBP) and Environmental Protection Agency (EPA). In addition, the Conservancy is required to draw upon their educational background, experience, professional symposia, and on-the-job training. Staff participates in technical workshops to share and expand their knowledge in their areas of expertise. Staff proficiency is demonstrated through workshop presentations, written reports, committee presentations, and Conservancy publications. The Conservancy's Director of Conservation Technology, Geospatial Program Manager, and Director of Administration will complete all necessary EPA Quality Assurance Classes.

Jeffrey Allenby, MEM, GISP, is the Conservancy's Director of Conservation Technology (10 years of experience in applications of GIS and remote sensing in land cover production, direct-detection methods for stream mapping, large landscape data processing, and contract oversight/management). Jeff will have overall responsibility for assigning appropriate personnel to complete the tasks included in this plan. He will ensure that the project budget is adhered to, and will communicate with the Project Manager on work accomplished in this plan and any problems or deviations that need to be resolved.

Jarlath O'Neil-Dunne, MS, is the Director of the Spatial Analysis Laboratory at the University of Vermont, and Faculty Research Associate in Rubenstein School of Environment & Natural Resources (Over 20 years of experience employing geospatial technology for land cover mapping, transportation decisions support, hydrologic modeling, feature detection, and national security applications). As head of the UVM Spatial Analysis Laboratory, Jarlath is responsible for creating initial land cover classifications, which will subsequently be modified and enhanced by the Conservancy.

LeeAnn King, MS, is the Conservancy's Geospatial Program Manager. LeeAnn has eight years of experience in international/interagency collaborative earth science research, resource measurements, and monitoring. She has expertise in applications of GIS and remote sensing for land cover and land cover change analysis with large landscape data processing, field-based surveys, machine learning and prescribing best management practices from field experimentation. LeeAnn is responsible for managing budgets, tracking deliverables, and coordinating effort among the Conservation Technology Team of the CIC at the Conservancy.

Rachel Soobitsky, MPS, is a Geospatial Project Manager at the Conservancy and serves as Project Manager for this project. Rachel has three years of experience in geospatial analysis and modeling. She has worked on producing land cover in several distinct regions of the US, including the desert southwest and mapping-tree-canopy change in Anne Arundel County. Rachel is responsible for primary creation of deliverables, technical coordination with project partners, as well as outreach and communication efforts.

See Figure 1-1. Organizational Chart

1.5 Problem Definition/Background (EPA QA/R-5 A5)

Updating the 2013/2014 high-resolution land cover dataset for the Chesapeake Bay watershed will be a multi-year effort that requires several components. The main effort will be the production of both land cover and land use classifications and change detection results for the Chesapeake Bay watershed (and intersecting counties).

Between June 2015 and December 2016, the Conservancy worked with UVM to create a high-resolution land cover and land use dataset for the watershed states and District of Columbia, for the imagery dates of 2013/2014 (through a partnership, Worldview Solutions created the land cover dataset for Virginia, specifically). This dataset has improved modeling for CBP as well as conservation and restoration planning efforts throughout the Chesapeake Bay watershed. Updating the 2013/2014 high-resolution land cover and land use datasets for the Chesapeake Bay watershed is key to analyzing how the landscape is changing and to track how the localities are progressing towards the EPA established total maximum daily load (TMDL) goals by 2025. As part of this initiative, the Conservancy and UVM will work to refine the data through stakeholder outreach, quality control, and accuracy assessments of the data produced.

To facilitate the incorporation of as much local data as possible, an important part of the process is for local governments to engage in the data development, as their localized knowledge will be invaluable in arriving at final land cover and land use classification maps. Stakeholder engagement will consist of several activities: coordinating with local governments to gather ancillary data sets, receiving feedback on data accuracy, and promoting the datasets as tools for local use. If counties fail to contribute local data, then state collected datasets will fill in for that location (if available).

All public facing datasets will meet the 2016 Metadata Technical Specifications, developed by the EPA. In addition, the metadata for each locality's land cover and land use dataset will include where any planimetric data used in the creation of the datasets originated from, and the date the planimetric data was created. If multiple sets of specific planimetric data exist for the same county or municipality, the Conservancy will determine which to use based on which has higher accuracy or is more current.

1.6 Project/Task Description and Schedule (EPA QA/R-5 A6)

- **Write a Quality Assurance Project Plan (QAPP) (December 2018)**
  This document will detail the proposed work plan and the general approach for the 6-year project. Specific information in the QAPP will include a project management plan, including personnel working on the project and organizational information; information about proposed methods, literature supporting the chosen methods, and how the source data will be collected; a plan for how we will ensure all activities are completed correctly; and a plan for how we intend to review and interpret the data before it is incorporated into secondary analyses.

- **Develop a Comprehensive Data Generation and Storage Plan (December 2018)**
  In conjunction with CBP and contractor staff involved in other Objectives, the Conservancy will create a data generation and storage plan that is intended to minimize the transfer of data between partners, maximize access to shared resources for both project partners and the general public, and ensure long-term sustainability of modeling efforts as new data becomes available. Specifically, within this plan, the Conservancy will address CBP's move towards hosting data in Amazon Web Services (AWS) and ensure partner organizations are able to easily access relevant datasets.

- **Identify methods to define areas of significant change in the Chesapeake Bay watershed (December 2018)**
  In Year 1, Conservancy and UVM staff will work with CBP and USGS staff to determine the most appropriate methods to assess change throughout the Chesapeake Bay watershed. We will assess

how well different models identify landscapes that have changed based on a combination of population growth models, 30-meter resolution change products, and high-resolution change products.

- **Collect local information to help inform classifications and land use conversion (January 2019)**
  A significant outreach effort will be made to engage local governments to collect data and specifications. Conservancy staff will focus on gathering, consolidating, and standardizing this data in preparation for the classification of change areas and the land use conversion process for these areas. Datasets will likely include, but not be limited to, parcel information, land use, locations of surface mines and landfills, zoning information, and any other datasets that can help provide context to the landscape.

- **Determine the feasibility and methods for a set of secondary classifications (March 2019)**
  Through consultation with CBP and USGS staff, it is evident that a set of secondary classifications could help with modeling efforts throughout the Chesapeake Bay watershed. These classes would be identified through alternate means than the base classification, and may include identifying non-tidal/forested wetlands; animal operations; vegetation height; aquaculture operations; vineyards, nurseries, greenhouses, and orchards; deciduous vs. evergreen trees; center pivot irrigation; crops vs. pasture; grass filter strips; and submerged aquatic vegetation. Conservancy and UVM staff will identify the most promising methods for completing each of these classifications and assess each for the feasibility of inclusion in future updates depending on budget, capacity and feasibility of mapping.

- **Create LiDAR derivatives for project partners to use internally (June 2019)**
  The Conservancy will identify common datasets that are required for multiple objectives, such as LiDAR-derived elevation models, and create a strategy for their requirements, timing, development, and storage to minimize redundant data processing tasks. Within this Objective, UVM will produce common, watershed-wide layers including a Digital Elevation Model, Digital Surface Model, LiDAR Intensity, and potentially other derived layers such as a Topographic Convergence Index. These layers will be created in consultation with staff working on Objective 2 to ensure the products are useful for other data analysis tasks. For areas where LiDAR data is out of date, we will assess the feasibility of using alternate datasets, such as Hexagon Geospatial's HxIP imagery, to provide height information.

- **Update high-resolution land cover for areas that have experienced significant change (June 2019 and Year 3)**
  Conservancy and UVM staff will conduct a watershed-wide analysis to identify areas of significant change that will provide the geographic constraints for an updated land cover dataset. Based on the output of the analysis, UVM will update the base land cover classification using the most recent aerial imagery and elevation data. This update will use the same schema as the previous land cover classification and will be used to track development trends and update the suite of TMDL models.

- **Create final classification schema for Year 2 wall-to-wall land cover update (June 2019)**
  In preparation for the wall-to-wall classification in Year 2, Conservancy and UVM staff will work with CBP partners and local government representatives to determine a final classification schema that will inform management efforts in the future.

- **Wall-to-wall land cover classification and manual corrections (Year 2 and Year 5)**
  Based on the schema determined in Year 1, UVM staff will complete the initial classification of approximately 100,000 square miles, covering all counties that touch the Chesapeake Bay watershed. UVM staff will then perform a manual corrections process to ensure that the data meets accuracy standards developed through consultation with the Land Use Workgroup and CBP Partners. After each wall-to-wall land cover classification is complete, the Conservancy will perform a change detection assessment between the new dataset, and previous. For example, once the 2017/18 wall-to-wall land cover is complete, a change detection will be performed between the 2013/14 and 2017/18 datasets.

- **Land Use Conversion (Years 3, and 6)**
  Conservancy staff will work with CBP modeling staff to perform a land cover to land use conversion on the wall-to-wall land cover from Years 2 and 5, in Years 3 and 6 (respectively). This process will take into account local data, including zoning and parcel information, and other ancillary datasets provided by local and state partners through the outreach efforts detailed above.

- **Accuracy Assessments (Years 3, 4, and 6)**
  Conservancy staff will conduct an accuracy assessment for the wall-to-wall land cover change products created in Years 2 and 5, in Years 3 and 6, and on the wall-to-wall land use dataset created in Years 3, in Years 4. The assessment will be conducted based on the methodology developed by the Conservancy as part of the Chesapeake Bay High-Resolution Land Cover dataset released in 2016. Due to the second wall-to-wall land use conversion being complete in Year 6, there may not be time to complete a second accuracy assessment on that dataset.

- **Lessons Learned Reports (Years 3 and 6)**
  Conservancy and UVM staff will draft Lessons Learned reports in Years 3 and 6, which will detail progress and advancements in land cover classifications, stakeholder outreach, and change detection to help inform future classification efforts.

	Year 1 (18/19)	Year 2 (19/20)	Year 3 (20/21)	Year 4 (21/22)	Year 5 (22/23)	Year 6 (23/24)
QAPP						
Hot Spot Methodology						
Hot Spot LC Updates	2013/14-2017/18		2017/18-2019/20			
Land Cover Classifications		2017/18			2021/22	
Land Use Conversions			2017/18			2021/22
Corrections (2013/14)						
Land Cover wall-to-wall Change						
Lessons Learned Report						
Accuracy Assessment						
Corrections						
Stakeholder Outreach						

If there is a possibility of delays in the above deliverables, the Conservancy is responsible for notifying CBP as soon as possible. The reason for the delay and the updated date of delivery should be included in the notice. In addition, if the delay will affect any of the other deliverables, it shall be noted.

Each county would benefit from the access to the products of Objective 1. Land Cover and Land Use data downloaders for our end-users have been cut from the budget, but it is highly recommended funding for this task be re-allocated in future project budgets. Local governments are more prone to share planimetric datasets knowing their data is helping to create a free and easily accessible product.

1.7 Quality Objectives and Projects Decisions (EPA QA/R-5 A7)

The objectives of this project are to create accurate 1-meter resolution land cover and land use datasets for the entire Chesapeake Bay watershed, at two time-steps. These datasets will be used in future growth modeling by CBP. In addition, the datasets will be used as baseline datasets for Objectives 2 and 3 of this EPA Grant. If the National Agriculture Imagery Program (NAIP) imagery continues to be updated on a 2-year schedule (as it has previously), then the time-steps for the dataset outputs are as follows: 2017/18 hot spot land cover and wall-to-wall land cover and land use datasets; 2019/20 hot spot land cover; and 2021/22 wall-to-wall land cover and land use datasets.

1.8 Documents and Records (EPA QA/R-5 A9)

The Conservancy will share the current version of the QAPP with all project staff and partners, including any revisions or updates that occur. In conjunction with CBP and project partners, the Conservancy will create a data storage and management plan that is intended to minimize the transfer of data between partners, maximize access to shared resources for both project partners and the public, and ensure the long-term sustainability of modeling efforts as new data becomes available. Specifically, within this plan, we will address CBP's move towards hosting data in AWS and ensure those partner organizations are able to easily access relevant datasets.

Relevant outputs include: 1) finalized land cover datasets, 2) finalized land use datasets, 3) Lessons Learned reports to document organizational development, 4) Accuracy Assessment reports, and 5) semi-annual progress reports.

The Conservancy will keep a copy of all datasets associated with EPA Program Funded Projects for at least five years after closeout of the agreement to act as a backup for CBP while ensuring data integrity during that time. The Conservancy Director and Geospatial Program Manager will ensure that the Conservancy will meet all data retention requirements set by CBP throughout the entire project implementation period for all Geospatial Support Objectives and all additional projects between the Conservancy and EPA associated agencies.

1.8.1 Semi-annual and/or Final Reports

The Conservancy will be responsible for organizing semi-annual reports as described in the project timeline above. Each semi-annual report will contain an update of outlined project activities, as well as any lessons learned in the course of project activities.

2.0 PRODUCT GENERATION

2.1 Sampling Design (Experimental Design) (EPA QA/R-5 B1)

The study area of the data products include any counties or municipalities that are within the Chesapeake Bay watershed boundary and includes the entire county if it touches the boundary. This includes over 100,000 square miles of land. The study area is shown in Figure 2 below. The wall-to-wall land cover and land use datasets, along with planimetric data collection and outreach will be performed for the following counties/municipalities:

Maryland: Allegany, Anne Arundel, Baltimore City, Baltimore, Calvert, Caroline, Carroll, Cecil, Charles, Dorchester, Frederick, Garrett, Harford, Howard, Kent, Montgomery, Prince George's, Queen Anne's, St. Mary's, Somerset, Talbot, Washington, Wicomico, and Worcester.

Washington D.C.

Delaware: New Castle, Kent, and Sussex.

West Virginia: Berkeley, Grant, Greenbrier, Hampshire, Hardy, Jefferson, Mineral, Monroe, Morgan, Pendleton, Pocahontas, Preston, Randolph, and Tucker.

Virginia: Accomack, Albemarle, Alleghany, Amelia, Amherst, Appomattox, Arlington, Augusta, Bath, Bedford, Botetourt, Buckingham, Campbell, Caroline, Charles City, Charlotte, Chesterfield, Clarke, Craig, Culpeper, Cumberland, Dinwiddie, Essex, Fairfax, Fauquier, Fluvanna, Frederick, Giles, Gloucester, Goochland, Greene, Hanover, Henrico, Highland, Isle of Wight, James City, King and Queen, King George, King William, Lancaster, Loudoun, Louisa, Lunenburg, Madison, Mathews, Middlesex, Montgomery, Nelson, New Kent, Northampton, Northumberland, Nottoway, Orange, Page, Powhatan, Prince Edward, Prince George, Prince William, Rappahannock, Richmond, Roanoke, Rockbridge, Rockingham, Shenandoah, Spotsylvania, Stafford, Surry, Warren, Westmoreland, York, City of Alexandria, City of Buena Vista, City of Charlottesville, Chesapeake, City of Colonial Heights, City of Covington, City of Fairfax, City of Falls Church, City of Fredericksburg, City of Hampton, City of Harrisonburg, City of Hopewell, Lexington, City of Lynchburg, City of Manassas, City of Manassas Park, City of Newport News, Norfolk, City of Petersburg, City of Poquoson, Portsmouth, City of Richmond, Roanoke, Salem, City of Staunton, Suffolk, Virginia Beach, City of Waynesboro, City of Williamsburg, City of Winchester, and Town of Clifton Forge.

New York: Allegany, Broome, Cayuga, Chemung, Chenango, Cortland, Delaware, Herkimer, Livingston, Madison, Oneida, Onondaga, Ontario, Otsego, Schoharie, Schuyler, Steuben, Tioga, Tompkins, and Yates.

Pennsylvania: Adams, Bedford, Berks, Blair, Bradford, Cambria, Cameron, Carbon, Centre, Chester, Clearfield, Clinton, Columbia, Cumberland, Dauphin, Elk, Franklin, Fulton, Huntingdon, Indiana, Jefferson, Juniata, Lackawanna, Lancaster, Lebanon, Luzerne, Lycoming, McKean, Mifflin, Montour, Northumberland, Perry, Potter, Schuylkill, Snyder, Somerset, Sullivan, Susquehanna, Tioga, Union, Wayne, Wyoming, and York.

2.2 Sampling Methods (EPA QA/R-5 B2)

The reason for performing outreach to all of the above counties and municipalities is to acquire updated planimetric data to aid in the creation of the land cover and for the conversion to land use. In addition, use cases will be collected and logged, along with feedback on the product and on the eventual accuracy in each locality. All data will be reviewed for potential incorporation into our analysis, and outreach efforts will reflect the locality's associated need and benefits of incorporating additional auxiliary data. As part of this outreach, the Project Manager will email each locality's GIS, Planning, and/or Zoning Departments, informing them of the project and requesting updated planimetric data. If there is no response after the initial outreach is performed, a second email will be sent to remind localities of the request. If there is still no response from the locality, a phone call will be made to the county's point of contact. In addition to reaching out to the localities, statewide organizations (such as the Maryland Department of Environment and Maryland Department of Planning and their counterparts in other states), will be contacted to collect additional datasets.

2.3 Analytical Methods (EPA QA/R-5 B4)

To perform the change detection analysis between a land cover classification and newer imagery dates, the Conservancy and UVM will spend time researching and developing change detection techniques. A “hot spot" approach will be used to detect areas that have had the most significant change throughout the entire Chesapeake Bay watershed. Once these "hot spots" are identified, a new land cover and land use classification will be created for these locations. The goal of this approach is to create updated data in those areas of highest change to help decision-makers track and quantify how these changes may impact progress towards the 2025 TMDL goals. The different methods that will be researched for the “hot spot” change detection analysis include: U.S. Census Population Data, Microsoft (MSFT) Artificial Intelligence (AI) created land cover, Land Change Monitoring, Assessment, and Projection (LCMAP) data, and American Community Survey (ACS) data. The U.S. Census Population Data that will be researched is the “County Population Totals and Components of Change: 2010-2017”. The MSFT AI land cover is at 1-meter resolution, including the following four classes: “tree canopy”, “impervious”, “water”, and “low vegetation”. The LCMAP data has a “change magnitude” layer that will be looked at, that is at 30-meter resolution. The ACS data is calculated on a census tract level.

The Conservancy and UVM will employ Object-Based Image Analysis (OBIA) techniques, which divides an image stack into homogeneous regions based on similarities between neighboring pixels (Blaschke 2010, O'Neil-Dunne et al. 2013; O'Neil-Dunne et al. 2014). Using these image objects, analysts will identify distinguishing characteristics of those regions and integrate the algorithms into a rule-based expert system, collectively known as a ruleset. For example, lakes and ponds typically return low amounts of near-infrared radiation and are of a certain size and uniform texture. Within the expert system, a series of segmentation, classification, and morphology algorithms are used to assign these features to the “water bodies” class. This approach allows for scalability, flexibility, and transferability. Post-classification, manual corrections will be performed by analysts to improve accuracy and appearance, with the assistance of local planimetric datasets incorporated where available, such as edge-of-pavement or roads. In an accuracy assessment of the last high-resolution land cover dataset, land cover results were deemed 90% accurate (Pallai and Wesson 2017). Ancillary data sets will be used to further aid the classification workflow, with final corrections done manually using the extracted imagery segments.

The work for the next iterations of wall-to-wall land cover will be completed solely by UVM to minimize discrepancies in the final dataset due to data being produced by different organizations not matching at the edges well, a common challenge in the first land cover classification. UVM will produce the core classification for the entire watershed and leverage expertise from similar projects, both completed and ongoing; including, developing tree canopy for the Northeastern United States as part of a National Aeronautics and Space Administration (NASA) Carbon Monitoring System project, the Chicago Regional high-resolution land cover mapping, and high-resolution land cover for the Delaware River Basin. UVM is best positioned to generate the land cover classification for the entire watershed based on their access to a student workforce, which offers a flexible and cost-effective labor pool that enables them to complete deliverables in a timely manner.

Data standards will need to be set before processing, including the land cover types to classify. Following the classifications from the 2013/14 land cover data set, the Conservancy and UVM propose to map the following classes: water, tree canopy, shrubland, low vegetation, barren, impervious (structures, roads, other), wetlands, and three tree canopy over impervious classes. This is subject to change per discussion between the partners, per Section 1.6 above “Create final classification schema for Year 2 wall-to-wall land cover update (June 2019)”. The definitions of the classifications from the 2013/14 land cover dataset are as follows:

1) The **water** class will include all areas of open water, generally with less than 25% cover of vegetation/land cover, including water-filled backyard pools, ponds, lakes, rivers, and natural tidal pools in wetland areas. Additionally, boats that are not attached to docks will be classified as water due to their ephemeral nature.
2) The **tree canopy** class will include deciduous and evergreen woody vegetation of either natural succession or human planting that is over approximately 5 meters in height. Stand-alone individuals, discrete clumps, and interlocking individuals are included.
3) The **shrubland** class includes deciduous and evergreen woody vegetation that is between approximately 2 and 5 meters in height. Stand-alone individuals, discrete clumps, and interlocking individuals are included, as are true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions.
4) The **low vegetation** class will include plant material of natural succession or human planting that is less than approximately 2 meters in height. This includes visibly tilled fields (with or without vegetation), lawns, nursery plantings with or without tarp cover, and natural ground cover.
5) The **barren** class will include areas void of vegetation consisting of natural earthen material regardless of how it has been cleared. This includes beaches, mudflats, dirt roads, and bare ground in construction sites.
6) The **impervious structures** class will include human-constructed objects made of impervious materials that are greater than approximately 2 meters in height. Houses, malls, and electrical towers are examples of structures.

7) The **impervious roads** class will include surfaces that are used and maintained for transportation, as denoted by planimetric data.
8) The **impervious (other)** class will include human-constructed surfaces through which water cannot penetrate, and that is below approximately 2 meters in height. This includes asphalt, concrete, gravel, pavement, treated lumber (e.g. docks and decks), buildings, driveways, sidewalks, parking lots, runways, some private roads, railroads and rail right-of-ways, and barren lands within industrial, transitional (early stages of construction), and warehousing land uses.
9) The **wetlands** class will include herbaceous vegetation areas that intersect or are near select National Wetlands Inventory (NWI) layers (Estuarine and Marine Wetland, Freshwater and Emergent Wetland, Freshwater Forested/Shrub Wetland, and Riverine), that are visually confirmed to have wetland characteristics (i.e. a look of saturated ground surrounding the vegetation), and that are located along major waterways (i.e. rivers, ocean). Areas of low vegetation near the NWI layers are included if they are visually confirmed to be wetland ecosystems. Woody vegetation (i.e. tree canopy and shrubland) is excluded from this category.
10) Lastly, there are three categories of tree canopy over impervious surfaces: **tree canopy over roads**, **tree canopy over structures**, and **tree canopy over impervious (other)**. In each case, this class will be selected if tree cover has been detected from the imagery and LiDAR data, but planimetric data or leaf-off orthophotos indicates that the ground is covered with an impervious surface. Collectively, we refer to these classes as the tree canopy over impervious (TCOI) classes.

After the initial land cover classification has been completed, the Conservancy, working in conjunction with CBP, will perform the land use conversion to match the class requirements of the Phase 6 Chesapeake Bay Watershed Model. The land use dataset will combine some classes, such as the "tree canopy over impervious classes", but split others. For example, "tree canopy" will be split into "forest" and "tree canopy over turf grass", and "low vegetation" will be split into "turfgrass", "cropland", and "pasture". To perform the land use conversion, the Conservancy will rework existing Python scripts from the 2013/14 land use conversion, which will then be deployed to AWS for processing. The Python script will be comprised of ancillary datasets, including planimetric data provided by localities, the aforementioned land cover classification, and outside datasets such as the National Wetland Inventory (NWI), CBP's Protected Lands dataset, etc.

<u>2.4 Quality Control Requirements</u> (EPA QA/R-5 B5)

UVM will perform quality assurance/ quality control (QA/QC) on the land cover dataset, to aim for the same or higher accuracy as the previous 2013/14 dataset, which has 90% accuracy.

<u>2.5 Data Acquisition Requirements (Non-Direct Measurements)</u> (EPA QA/R-5 B9)

The land cover classifications will be based on NAIP images, freely available to the public from the US

Department of Agriculture (USDA). NAIP imagery is acquired at a 1-meter ground sample distance (GSD) with a horizontal accuracy that matches within six meters of photo-identifiable ground control points, which are used during image inspection.

Where available, the project will use LiDAR data to help distinguish land cover by indicating the heights of various features as well as their reflectivity. LiDAR data is expensive to produce, and a single contiguous dataset will not be available for the entire Chesapeake Bay watershed. The Conservancy and UVM will work with available public LiDAR data, as accessed at the following website: http://coast.noaa.gov/inventory.

A significant outreach effort will be made to engage local governments to collect data and specifications. The Conservancy staff will focus on gathering, consolidating, and standardizing this data in preparation for the classification of change. Datasets will likely include, but not be limited to parcel information, land use, locations of surface mines and landfills, zoning information, and any other datasets that can help provide context to the landscape.

2.6 Data Management (EPA QA/R-5 B10)

In conjunction with CBP and project partners, the Conservancy will create a data storage and management plan that is intended to minimize the transfer of data between partners, maximize access to shared resources for both project partners and the public, and ensure long-term sustainability of modeling efforts as new data becomes available. Specifically, within this plan, we will address CBP's move towards hosting data in AWS and ensure those partner organizations are able to easily access relevant datasets.

Additionally, the Conservancy will identify common datasets that are required for multiple activities, such as LiDAR-derived elevation models, and create a strategy for their requirements, timing, development, and storage to minimize redundant data processing tasks. Within this Objective, UVM will produce common, watershed-wide layers including a Digital Elevation Model, Digital Surface Model, LiDAR Intensity, and potentially other derived layers such as a Topographic Convergence Index. These layers will be created in consultation with staff working on Objectives 2, 3, and 4 to ensure the products are useful for other data analysis tasks. For areas where LiDAR data is out of date, we will assess the feasibility of using alternate datasets, such as Hexagon Geospatial’s HxIP imagery, to provide height information.

3.0 ASSESSMENT AND OVERSIGHT

3.1 Assessments/Oversight and Response Actions (EPA QA/R-5 C1)

The Conservancy and UVM staff will complete semi-annual progress reports that will detail project activities for each six-month period, including progress toward completing timeline objectives and a roadmap for the upcoming period. These reports will be somewhat brief and are intended for ongoing communication only.

In addition, Conservancy and UVM staff will draft Lessons Learned reports for objectives defined in the Work Plan. The Lessons Learned Report will detail in a more formal way the progress and advancements in land cover classifications, stakeholder outreach, and change detection to help inform future classification efforts.

3.2 Reports to Management (EPA QA/R-5 C2)

The Project Manager will provide as-needed updates to CBP, such as when important progress is made or achievements are met. The Project Manager will also attend Land Use Work Group meetings when requested, to provide updates on the progress of the project. These activities will be in addition to the semi-annual progress reports. Internally at the Conservancy, the Project Manager will meet with the analyst team weekly to check up on the progress of the work as related to the timeline and brainstorm with the analyst on any technical tasks. The Project Manager will meet with the Program Manager and Director on an as-needed or monthly basis to report on any updates to the project or to relay any questions that may arise.

4.0 DATA REVIEW AND USABILITY

4.1 Data Review, Verification, and Validation Requirements (EPA QA/R-5 D1)

The Conservancy and UVM staff will work to define QA/QC standards to efficiently and effectively provide data of high quality for inclusion in mapping and modeling tasks. These standards will guide the level of detail staff will use when making manual corrections. The Conservancy will conduct an accuracy assessment for the change products and the wall-to-wall land use classification. The assessment will be conducted based on the methodology developed by the Conservancy as part of the Chesapeake Bay High-Resolution Land Cover dataset released in 2016 and improved on throughout the development of the project. QA/QC and Accuracy Assessment applications are explained in detail in the QAPP for each objective.

4.2 Verification and Validation Methods (EPA QA/R-5 D2)

Accurate and precise land cover data is critical in planning for a myriad of conservation and restoration goals, including pollution contribution modeling and riparian forest buffer coverage. The increased accessibility of high-resolution imagery has led to the need for updated protocols in the assessment of land cover classification accuracy. In response, the Conservancy will employ an object-based validation approach and will assess the agreement between multiple reviewers to ensure an unbiased evaluation. Consideration has been given to land cover and land use transitional stages that may be captured in the classification. Our protocol is designed such that these conditions do not negatively influence the accuracy of the dataset.

The accuracy assessment protocol which we will employ is based on the accuracy assessment conducted for the 2013/14 land cover product. In that assessment, randomized points were sampled from the overall dataset, and labeled whether or not the classification was correct or incorrect. If disagreement occurred, or if one of the reviewers indicated that the pixel was indistinguishable, then a third reviewer would provide an additional assessment of the accuracy of that sampled pixel. Based on this accuracy assessment, the 2013/14 land cover dataset achieved an estimated accuracy of 90% across the watershed, which would be a worthwhile accuracy goal for each subsequent round of land cover. However, given advances in the field, it is possible that this accuracy could be surpassed.

Our accuracy assessment methodology has been developed because approaches for evaluating coarser-resolution data, such as land cover derived from Landsat or MODIS satellites, often are not appropriate for high-resolution datasets. Such as in the case with the high-resolution land cover dataset, 1-meter data is too precise in scale to support a pixel-based assessment. Whereas the more commonly available 30-meter resolution data allows the analyst to zoom into the area captured by a pixel and, with higher resolution imagery, observe the land cover class within that 30-meter square. At one-meter resolution, it is usually too difficult to identify a single pixel's classification without taking the area surrounding it into context. Consequently, object-based accuracy assessments have been proven to be a more effective accuracy assessment methodology for high-resolution land cover classifications.

4.3 Reconciliation with User Requirements (EPA QA/R-5 D3)

The Conservancy has adopted a policy for all federally funded grants, consistent with the Presidential Executive Order # 12906, that all data generated or collected using federal funds, submitted to CBP, or served on the Internet via Chesapeake Center for Collaborative Computing, also known as C4, shall be accompanied by metadata (descriptive information about the data), that fully conforms to the Federal Geographic Data Committee's requirements for metadata and National Biological Information Infrastructure's (NBII) Metadata Standard, where applicable. The FGDC guide for creating metadata is the Content Standard for Digital Geospatial Metadata Workbook (www.fgdc.gov/metadata).

Data to be accessed on the Internet via C4 must follow the C4 Metadata Reporting Guidelines established by the Chesapeake Bay Program. This guideline was established to facilitate entering consistent, accurate metadata to ensure the information about the Chesapeake Bay will be easily available and used appropriately. The C4 Metadata Reporting Guidelines is also accessible on the C4 Internet Web Page and will be adhered to in all Conservancy documents and datasets hosted on C4. The COMET system (www.chesapeakebay.net/comet) provides a streamlined, easy to use tool for entering metadata that meets C4 and FGDC requirements.

The project team will draw from experiences creating the datasets and writing the semi-annual and Lessons Learned reports to identify any anomalies or limitations of the data. These anomalies and limitations will be documented clearly in the metadata of all datasets produced as part of this objective.

5.0 REFERENCES

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6.0 FIGURES

Figure 1. Organization Chart

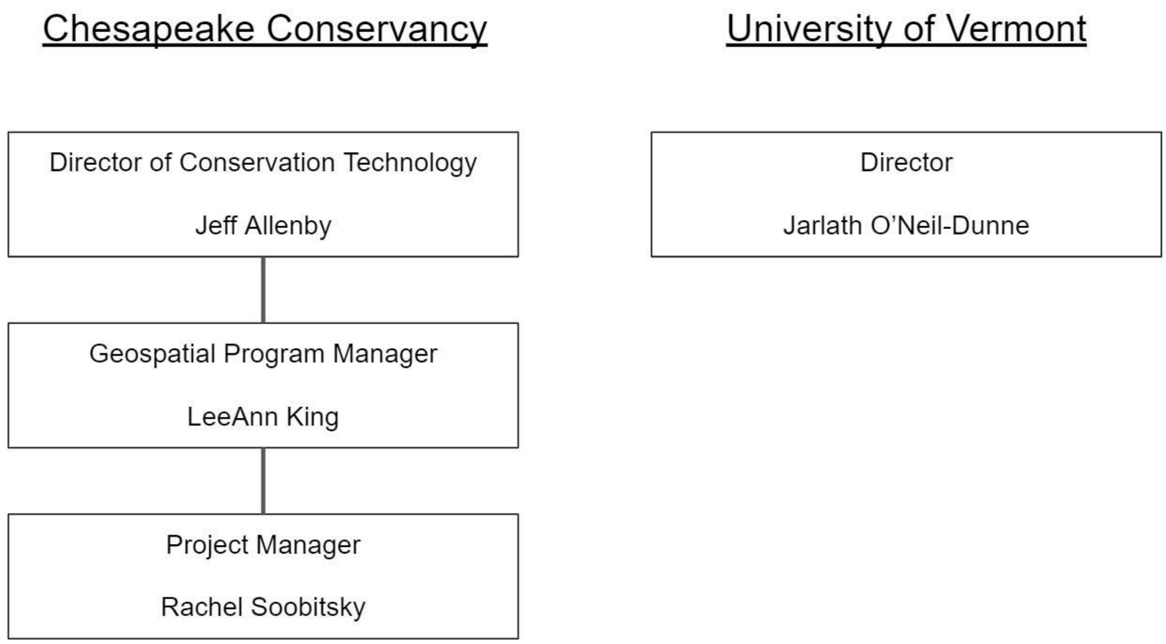

Figure 2. Site Map with Sampling Locations