Land Use Methods & Metrics Development and Land Use Options Evaluation Combined Outcome Management Strategy

2015–2025, v.3

Photo by Will Parson / Chesapeake Bay Program

I. Introduction

To minimize the extent, and mitigate the effects of land conversion, local decision-makers and the land conservation community need to be informed about: 1) land cover and use changes that affect wildlife and stream habitats, watersheds, and human communities; and 2) policy options, incentives, and tools that reduce the rate and magnitude of land conversion. This strategy represents a combined approach for the Land Use Methods and Metrics (LUMM) Development and Land Use Options Evaluation (LUOE) Outcomes. This strategy seeks to address this first need by calling for monitoring and reporting on the rates of farmland, forest and wetland conversion as well as the rate of impervious surface change at a local scale that is influenced by land use decisions. The Metrics Outcome will help inform outreach efforts and products developed as part of the Land Use Options Evaluation Outcome which will address the second need.

Preventing the loss of forests and wetlands by minimizing the amount of natural lands consumed by new development is the best method for retaining the natural hydrology and pollution control that these lands provide to the Chesapeake Bay watershed. Although farms alter hydrology and add nutrients and sediment to the watershed, conserving farmland is an important local, state and federal priority for a variety of reasons including, food production and capacity and rural economic development. Simultaneously, strengthening our towns and cities through smart growth provides many quality-of-life and economic benefits.

The population of the watershed is expected to grow by 2 million people, or the equivalent to 770,000 households by 2030. The loss of natural and rural land is dependent on the amount of land each new home consumes. For example, if each new household consumes two acres, rural and natural lands could decrease by as much as 1.5 million acres, but if they consume one-quarter acre, as little as 200,000 acres could be lost. Although traditional land conservation - land purchase, preservation easements - can help to direct new populations into designated or existing growth areas, additional land use “policy options, incentives and planning tools” as called for in the LUOE outcome are also needed to “reduce the rate of conversion of agricultural lands, forest and wetlands”. Achieving these outcomes requires not just protection of our rural and natural lands, but also considering growth options within our rural towns, cities and suburban areas that can effectively increase densities and attract new residents, while still providing for public open space

The intent of the LUMM and LUOE Outcomes are to develop a method and metrics to monitor the conversion of valued natural and working landscapes, such as forests, wetlands and farms and to better understand the impacts of land conversion and to provide tools and support to local governments to ensure their capacity to plan for and mitigate land change impacts. Natural and working landscapes provide ecosystem services of value to the Chesapeake Bay watershed and its population, including water quality and quantity, habitat, recreation and food production.

II. The LUMM and LUOE work hand and hand to develop a watershed-wide methodology and local-level metrics for characterizing the rate of farmland, forest, and wetland conversion, measuring the extent and rate of change in impervious surface coverage and quantifying the potential impacts of land conversion to water quality, healthy watersheds and communities. Both outcomes seek to educate and work with local governments leadership to improve their capacity to reduce the rate of conversion of agricultural lands, forests and wetlands as well as the rate of changing landscapes from more natural lands.Goal, Outcome and Baseline

This management strategy identifies approaches for achieving the following goal and outcomes:

Land Conservation Goal I

Conserve landscapes treasured by citizens in order to maintain water quality and habitat; sustain working forests, farms and maritime communities; and conserve lands of cultural, indigenous and community value.

Land Use Methods and Metrics Outcome

Continually improve the knowledge of land conversion and the associated impacts throughout the watershed. By 2016, develop a Chesapeake Bay watershed-wide methodology and local level metrics for characterizing the rate of farmland, forest and wetland conversion, measuring the extent and rate of change in impervious surface coverage and quantifying the potential impacts of land conversion to water quality, healthy watersheds and communities. Launch a public awareness campaign to share this information with citizens, local governments, elected officials and stakeholders.

Land Use Options Evaluation Outcome

By the end of 2017, with the direct involvement of local governments or their representatives, evaluate policy options, incentives and planning tools that could assist them in continually improving their capacity to reduce the rate of conversion of agricultural lands, forests and wetlands as well as the rate of changing landscapes from more natural lands that soak up pollutants to those that are paved over, hardscaped or otherwise impervious. Strategies should be developed for supporting local governments' and others' efforts in reducing these rates by 2025 and beyond.

Baseline and Current Condition

The temporal baselines for the Land Use Methods and Metrics outcome are the years 2013 (New York, Pennsylvania, District of Columbia, Delaware, and Maryland) and 2014 (Virginia, and West Virginia) for which 1-meter resolution land cover and land use data exist for all counties located within the Bay watershed. "Hot spots" of land change are monitored every two years while completing watershed-wide remapping of these counties every four years (2017/18, 2021/22).

The economy, consumer preferences and public investments influence the decisions of private developers and businesses which in turn influence the migration of people seeking jobs and amenities resulting in both commercial and residential growth. These factors, however, can be unpredictable and volatile as witnessed in the steep decline in new housing over the period of 2006-2009 following a boom and the impacts of COVID and other human population patters continue to evolve on the landcape Therefore, measured rates of land conversion should be interpreted in context relative to measures of economic activity such as population, employment growth and episodic large-scale infrastructure projects.

The LUMM outcome is on course with tremendous progress made including the finalization of a 1-meter resolution, 54-class land use/land cover (LULC) dataset for all counties within and adjacent to the Chesapeake Bay watershed for 2013/14 and 2017/18. These data are now informing the Bay watershed model (CAST-21), Chesapeake Healthy Watershed Assessment, Chesapeake Data Dashboard, the Community Tree Cover Indicator, Impervious Surface Indicator, and County Tree Cover Fact Sheets. The 1-meter LULC data are viewable and downloadable on the web . These data will be used to inform additional indicators developed as part of this outcome over the coming year including metrics on the rates of land conversion (i.e., forest, wetland, and productive lands converted to development), riparian forest extent and change, and effective impervious cover extent and change. These metrics and the associated high-resolution LULC data will also inform ten other outcomes outlined in the 2014 Chesapeake Bay Agreement.

The Land Use Options Evaluation Outcome calls for:

- Evaluation, by the end of 2017, of "policy options, incentives and planning tools" that can help local governments to "reduce the rate of conversion of agricultural lands, forest and wetlands", and
- Development of strategies to support "local governments' and others' efforts in reducing" the "rate of conversion of agricultural lands, forest and wetlands" by 2025 and beyond.

Efforts to date have compiled "policy options, incentives and planning tools" implemented at the local or state level have been most effective at reducing land conversion rates. There remains a need to determine whether the compilation of existing studies and reports on "policy options, incentives and planning tools" placed on the Bay Program website (under the second task) is sufficient to meet their needs; and if not, what more do they need to achieve a reduction in land conversion rates.

The data and statistics developed from the land use metrics will improve the connection of the LUMM and LUOE outcomes. How will the metrics and policy implementation be "measured" over time. How do we know if we are successful or done? A new land use strategy needs to be inclusive of land conservation, public access/recreation, land use planning, climate resiliency, and environmental equity and justice. It should be very explicit about defining the value-added role of the CBP Partnership in managing growth given that land use change is a phenomenon driven by the interplay of economics, cultural preferences, episodic events, and a wide-range of policies that cannot all be controlled. A new land use strategy integrated across multiple CBP workgroups and GITs, with the direct involvement of locals is needed that focuses on: 1) incentivizing infill and redevelopment, particularly in underserved minority communities; 2) facilitating public outdoor recreation and environmental education through land conservation; 3) maintaining ecosystem services and healthy watersheds while minimizing climate impacts on infrastructure; and 4) addressing local concerns (that may only be tangential to CBP concerns).

III. Participating Partners

The following partners have pledged to help implement this strategy:

- Chesapeake Bay Commission
- Land Use Workgroup
- Local Government Advisory Committee
- Local Leadership Workgroup
- Water Quality Goal Implementation Team
- Habitat Goal Implementation Team
- Healthy Watersheds Goal Implementation Team
- Maryland Department of Planning
- Pennsylvania Department of Community and Economic Development
- U.S. Geological Survey
- USGS National Geospatial Program
- The Chesapeake Conservancy

Local Engagement

To assist in quantifying impacts on communities, the Land Use Workgroup will work with the Local Government Advisory Committee (LGAC) and the Local Leadership Workgroup to identify local governments interested in better understanding local rates of, and impacts from, land conversion, and in using new tools for better managing the rates and impacts from land conversion. Local government stakeholders are needed to advise the Chesapeake Bay Program on the local relevance of land change and impact metrics (i.e., are the metrics adequate to inform land use planning activities at the county level).

This LUOE specifically calls for the direct involvement of local governments. Local government's specific role in achieving this outcome is to assist the Bay Program with evaluating policy options, incentives and planning tools. While not called for specifically, local government should be consulted in developing strategies to support efforts to reduce the rate of conversion. In addition, the advice, guidance and direct assistance of LGAC, LLWG and others will be needed throughout the process of implementing this management strategy.

IV. Factors Influencing Success

The following are natural and human factors that influence the ability of the Chesapeake Bay Program (CBP) to attain this outcome:

- Development of separate metrics: The CBP Management Board has interpreted the Outcome language as calling for the development of separate metrics for forest, farm, and wetland conversion in addition to measuring the rate of impervious surface change. For example, addressing this Outcome requires metrics that account for conversion from forests to farms and from farms to forests, in addition to conversions of both forests and farms to development.
- Sustainability of long-term monitoring: This factor is a question of political will more than technological capabilities. Continued monitoring of high-res land use change through the year 2034 is needed to support the achievement of multiple outcomes and the Phase 7 model. There remains a need to monitor land use change for an additional 5 years and meet the following objectives:
    - Adapt to changes in technology and CBP needs while ensuring consistency over time;
    - Couple monthly satellite imagery with more periodic aerial imagery;
    - Leverage advances in computational power and artificial intelligence;
    - Address the needs to monitor wetland change for black ducks, anadromous fish, and climate resiliency;
    - Evaluate effectiveness of the data for BMP verification.
    - A subsequent 5-year agreement needed to cover the years 2029-2034.
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- Methodology for assessing landscape change with high-resolution data with sufficient precision to inform county-level decisions: Techniques to separate actual change in land cover from false change. Change detection methods are rapidly advancing but are not sufficiently established to make this a non-issue. To accurately track change, updates to existing high-resolution land cover and land use datasets will be required during each four-year remapping phase. This will ensure that the data for 2013/14 are consistent with and directly comparable to the data for 2017/18 and those for 2021/22 and beyond

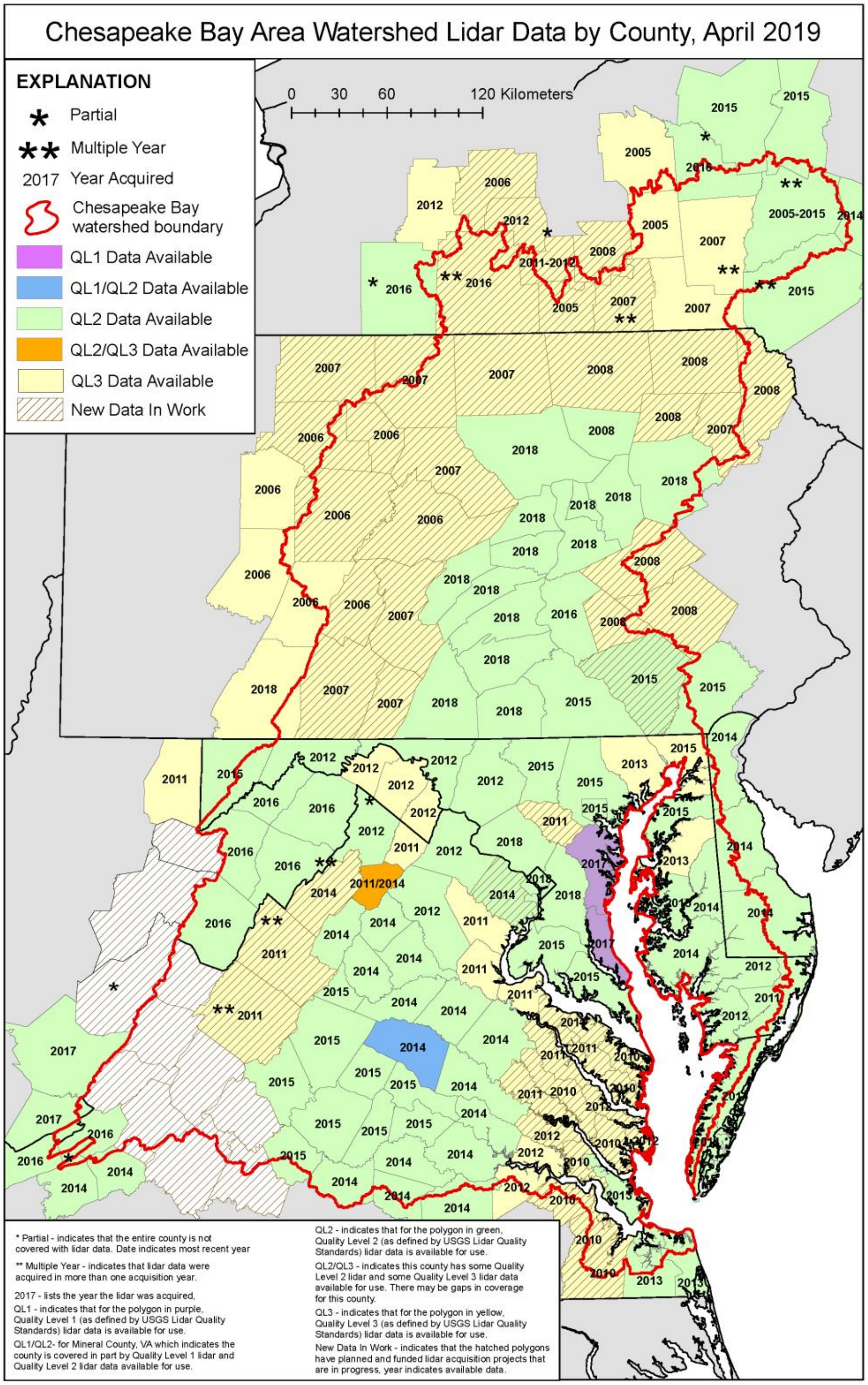
- Methodology to quantify impacts to communities and the environment: The quantification of impacts from land conversion to communities and the environment need to be explored in more detail and with input from local governments. Quantification of impacts without sufficient context for interpreting those impacts may lead to false conclusions.

V. Current Efforts and Gaps

The term "land cover" refers to the classification of land surface characteristics into categories such as impervious surfaces and tree canopy. Land cover classifications are derived from aerial and satellite spectral imagery collected from passive sensors (e.g. photography, thermal, infrared). These classifications can be enhanced by incorporating data from active sensors (e.g. weather sensors). Since the late 1990's, the CBP has relied on 30 meter-resolution Landsat satellite derived land cover data to provide a spatially consistent representation of Chesapeake Bay watershed conditions to inform the suite of models used for management purposes and for tracking changes on the landscape. The U.S. Geological Survey (USGS) has recently produced annual 30-meter resolution, 9-class (e.g., impervious, tree canopy) land cover data derived from Landsat imagery for the Bay watershed for the period 1985 – 2017 (https://www.usgs.gov/land-resources/eros/lcmap). In addition, the USGS has produced more detailed, 16-classes (e.g., pasture, deciduous forest, water), land cover classifications for the years 1984, 1992, 2001, 2004, 2006, 2008, 2011, 2013, and 2016 (https://www.mrlc.gov/data). These data are invaluable for highlighting "hot spots" of change and for informing the Bay watershed model but they can largely miss the development of two-lane roads and low-density residential areas. While these data have an overall accuracy around 80%, this is likely insufficient for monitoring change at a scale relevant to county-level decisions every 3-5 years.

Since the early 2000's, counties, states, and the United States Department of Agriculture Farm Service Agency (FSA) have acquired high-resolution (under two meter) imagery to inform transportation, public works and natural resource decisions. Initially, these data were acquired as natural color images and used as pictures, rather than analyzed as data. This practice has gradually evolved through the development of object-based feature extraction software, such as Feature Analyst, ENVI, and eCognition as well as the acquisition of imagery with a near-infrared spectral band in addition to the three visible bands. The near-infrared band enhances the ability to distinguish vegetation from non-vegetated areas.

At present, the FSA collects four-band leaf-on one-meter resolution ortho-imagery for each state as part of their National Agriculture Imagery Program (NAIP) every 1-3 years. Collection dates are cyclic and vary due to the availability of state cost-share funds and other factors. In addition, the Virginia Institute of Marine Science (VIMS) collects and manually classifies black and white aerial photographs along the near-shore areas of the Chesapeake Bay and its tidal tributaries to support their annual inventory of submerged aquatic vegetation (SAV) extent and density. Some states and localities acquire sub-meter leaf-off imagery every 3-5 years to support transportation and planning needs. Leaf-on imagery is better for detecting vegetation and leaf-off imagery is better for detecting impervious surfaces and water features which may be obscured by the canopy during the growing season. Leaf-off imagery is mostly collected during the spring, but the collection years often vary by state.



luence

http://gis.chesapeakebay.net/lidarstatus/. For more information on LiDAR specifications, see: https://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf

LiDAR (Light Detection and Ranging) refers to a high-resolution (under two meter) active airborne sensor that emits pulses of light in near-infrared (topographic LiDAR) and/or blue-green (topo/bathymetric LiDAR) wavelengths. These pulses are directed towards the ground, reflect off surfaces (e.g., buildings, leaves, branches, pavement, dirt), and return to the sensor. The time it takes for the pulses to be detected is recorded and correlated with the travel distance or "range" of each pulse. Because the exact location of the airplane in three-dimensional space is known, travel distances can be converted to elevations revealing a wealth of information about vegetation height, structure, biomass, and ground surface characteristics. As of April 2019, LiDAR imagery has been collected on a county-by-county basis at least once (occasionally twice or three times) for approximately 95% of the counties in the Bay watershed through 2004 - 2018. By summer 2020, LiDAR data will exist for all watershed counties (Figure 1).

There are different types of airborne LiDAR (e.g., waveform, discrete return, pulse width, and photon counting) which are not discussed here. The LiDAR data characteristics most relevant to the CBP needs are spatial accuracy, vertical accuracy, and penetration through water. Accuracies are influenced partly by the height and speed of the plane and frequency of pulses. The National Digital Elevation Program has developed a convention for characterizing the quality of elevation datasets. Most of the LiDAR elevation data currently available in the Chesapeake Bay watershed are classified as either Quality Level 2, "QL-2" (nominal pulse density of ≥ 2.0 pls/m^2; 10 cm vertical RMSEz) or "QL-3" (nominal pulse density of ≥ 0.5 pls/m^2; 20 cm vertical RMSEz). The QL-2 products have sufficient accuracy to produce a 1m resolution Digital Elevation Model (DEM) or Digital Surface Model (DSM) whereas the QL-3 products only support the production of a 2-3m resolution derivative products. Quality Level 1, "QL-1", data are now available for three jurisdictions and have nominal pulse density of ≥ 8.0 pls/m^2; 10 cm vertical RMSEz. These LiDAR products have mostly been collected using laser pulses with near-infrared wavelengths that cannot penetrate through water. Surface waters are depicted as flat, constant elevation surfaces similar to some building and pavement surfaces. Bathymetric and topo-bathy LiDAR instruments emit pulses in the blue-green wavelength that can penetrate water surfaces up to depths of 1- 10 meters depending on water clarity. Submerged surface elevations are also more accurate if the substrate is hardened (e.g., oyster bed) vs. soft (e.g., mud).

Coupling LiDAR data with high-resolution spectral imagery has proven very useful for improving the accuracy of semi-automated land cover classifications (e.g., differentiating buildings from parking lots and forests from scrub-shrub and herbaceous vegetation). The more data informing a classification (e.g., number of spectral bands, elevation and biomass data, parcels, and land use), the more automated the process can become to produce an accurate product. The costs of production are generally positively correlated with the degree of automation, yet all products require some level of manual editing to increase overall and individual class accuracies above 90%.

In 2015, 1-meter land cover data were produced for the entire Bay watershed (including all adjacent counties) using a combination of 2013/14 leaf-on NAIP imagery, available state or county leaf-off imagery and a Digital Surface Model (first return indicating the tops of surfaces) derived from LiDAR.[1] In 2016, the land cover data was translated into 1-meter land use by the CBP GIS Team.[2]

The Metrics Outcome calls for "continually improving the knowledge of land conversion" which requires attention towards monitoring land change rather than just mapping land cover once or periodically.

[1] https://chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-cover-data-project-2/
[2] https://chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-use-data-project/

Assessing and mapping land use and cover change from high-resolution imagery is challenging but holds great promise for meeting the objectives of this outcome. Changes in spectral surface-reflectance properties over multi-date images, however, introduce a lot of noise (i.e., misleading information) into interpretations of change. Sources of noise might include variations in sun-angle, atmospheric conditions, vegetation phenology and infrastructure materials. Image properties can also vary from one image tile to another and from one year to another. These problems are largely absent when performing a change analysis on 30-meter resolution Landsat satellite imagery which makes it ideal for "hot spot" change detection. High-resolution change analysis can be done, but for the above stated reasons, first-round automated results will likely be noisy and require modification to realize the accuracies needed to detect the average amount of change expected over a 2 to 4-year interval (~1% of the landscape).

VI. Management Approaches

There are three elements to the Metrics Outcome:

1. Monitor the rates of impervious surface change and conversion of forests, wetlands and farmland.
2. Quantify the impacts of land conversion on:
   a. Water quality.
   b. Healthy watersheds.
   c. Communities
3. Communicate results to the public, elected officials and to the CBP.

The CBP will coordinate and solicit input on user requirements and technical specifications for this outcome. There are three basic technical approaches for monitoring land conversion every 2-4 years: 1) coarse, 30-meter resolution watershed-wide mapping of land cover change from Landsat satellite imagery; 2) high-resolution (under five meter) watershed-wide mapping of land cover change from aerial or satellite imagery; and 3) high-resolution (under five meter) stratified random sampling. Each of these options has advantages and disadvantages related to cost, accuracy, spatial and temporal scale, flexibility for management use, adaptability to changing management objectives and educational value. These attributes were considered in developing recommendations for monitoring land change over time. Note that the above options are not necessarily mutually exclusive. For example, monitoring land change with Landsat satellite imagery can inform a stratified-sampling framework using high-resolution imagery. An area can be stratified into sections based on the amount of change detected by satellite imagery to ensure that all areas of high-change sections are included within a sample. Additional approaches, such as the use of artificial intelligence to classify high-resolution imagery, may emerge in the future given rapidly advancing technologies and techniques.

While measuring current rates of land conversion will require use of existing imagery and data which varies in spatial resolution, accuracy and acquisition year, significant improvements in derived metrics and cost savings to local, state and federal government agencies could be achieved through a coordinated effort to synchronize the acquisition of imagery and agree on a classification schema and change detection approach.

Quantifying the impacts of land conversion on water quality will be accomplished through close coordination with the CBP Modeling Workgroup and utilize the same sets of assumptions and data used to inform water quality decisions associated with the Chesapeake Bay Total Maximum Daily Load (TMDL). Quantifying impacts to healthy watersheds will be determined through close coordination with the Habitat and Healthy Watersheds Goal Implementation Teams (GITs) and may involve measures of vulnerability to urban development coupled with hydrologic impact measures associated with stream flow alteration. Assessing the impacts of land conversion to communities is one of the most complicated aspects of this outcome. Land conversion associated with residential and commercial development provides economic benefits to communities, but also involves costs that are not always evident at the time of development. Local participation will be sought to help identify and describe impacts to communities and to develop and implement the engagement strategy as described below.

Approaches Targeted to Local Participation

Local participation in developing impact methodologies, particularly those used to assess impacts to communities, are needed to ensure the data are useful for informing local-level decisions. The CBP Land Use Workgroup will work with LGAC, the Local Leadership Workgroup and the Communications Workgroup to help develop a local engagement strategy that seeks to target outreach efforts and integrate and disseminate products from this outcome and those from the Land Use Options Evaluation outcome.

Cross-Outcome Collaboration and Multiple Benefits

Restoration and conservation efforts in the watershed will benefit from the availability of high-resolution land cover and elevation data produced every 2-4 years. The data will inform all goals and almost all of the outcomes specified in the *Chesapeake Bay Watershed Agreement*—particularly the Vital Habitats, Healthy Watersheds and Land Conservation Outcomes. Specific benefits include:

- Characterizing, mapping, and tracking of wetlands, riparian forest buffers, forests and impervious surfaces;
- Characterizing, mapping, and tracking habitat conditions;
- Developing habitat suitability maps;
- Prioritizing and targeting restoration, conservation, education and public access efforts;
- Understanding the effects of management actions on water quality;
- Verifying riparian buffer and urban tree canopy best management practices (BMPs);
- Verifying the effects of land policy BMPs;
- Assessing the vulnerability of watersheds and stream restoration BMPs to altered flow regimes;
- Improving the accuracy of nutrient and sediment load estimates; and
- Educating people on the value and location of high-functioning landscapes.

VII. Monitoring Progress

N/A

VIII. Assessing Progress

Progress in developing the methods and metrics will be assessed quarterly by the Land Use Workgroup and will be based on the feasibility and accuracy of the derived metrics and impact measures. Following development and approval of the metrics, they will be reassessed every 2-4 years corresponding to the receipt of updated land cover information.

IX. Adaptively Manage

The utility of the metrics and impact assessments for informing CBP decisions will be evaluated at the end of each monitoring cycle and adjusted as needed to improve their utility for local decisions to accommodate changes in technology and programs.

X. Biennial Logic & Action Plan

Biennial logic and action plans for each management strategy will be updated to accompany this management strategy. The Combined Land Use Methods and Metrics Development and Land Use Options Evaluation outcomes Logic & Action Plan will update the following information:

- Key actions.
- Timeline for the action.
- Expected outcome.
- Partners responsible for each action.
- Estimated resources.