Technical Plan of Operations

Virginia Statewide Land Cover Data Development

Developed by

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1. Document Information

1.1 Document Responsibilities

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1.2 Document History

Date	Version	Revisions Made
7/1/2015	1.0	Technical Plan of Operations delivered to VGIN / DEQ
7/10/2015	2.0	Land Classification Updated
8/5/2015	3.0	Land Classification Updated
9/17/2015	4.0	Land Classification Updated and Technical Workflow Appendix included
12/1/2015	5.0	Technical Workflow Appendix updated
1/12/2016	6.0	Land Classification and Technical Workflow updated
5/6/2016	7.0	Tree accuracy and additional Pasture methodology updated

1.3 Acronyms and Definitions

Acronym	Definition
AgCensus	US Department of Agriculture – Census of Agriculture
ArcGIS	Esri's Flagship GIS product suite
DTM	Digital Terrain Model
Esri	Supplier of Geographic Information System software, web GIS and geo-database management applications
EPA	Environmental Protection Agency
GIS	Geographic Information Systems
NAIP	National Agriculture Imagery Program
NHD	National Hydrography Dataset
NRCS	Natural Resources Conservation Service

Acronym	Definition
NWI	National Wetlands Inventory Dataset
TPO	Technical Plan of Operations
VBMP	Virginia Base Mapping Program
VIMS TMI	Virginia Institute of Marine Science – Tidal Marsh Inventory
VDCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDMME	Virginia Department of Mines, Minerals and Energy
VDOF	Virginia Department of Forestry
VGIN	Virginia Geographic Information Network
WorldView	WorldView Solutions Inc, Land Cover data development vendor

1.4 Purpose

This Technical Plan of Operations document provides a detailed blueprint for the approach to the development of a statewide Land Cover database for the Virginia Geographic Information Network and its partners, detailing project methodology and techniques, quality assurance procedures, and any applicable preliminary database design documentation. This document outlines the goals of this project and the strategy and methods to achieve successful project completion. Throughout the project implementation, this document will be revised to reflect any adjustments made to the project approach and methodologies and changes will be tracked in Section 1.2 - Document History.

2. Project Goals and Methodology

WorldView Solutions project methodology focuses on capturing developing the statewide Land Cover dataset. The following is a summarized understanding of the main tasks to be completed for this project:

- Compile Source Data
- Develop Pilot Project
- Develop Deliverable Areas
- Prepare Imagery
- Create Training Data
- Set up Learning Parameters
- Conduct Supervised Feature Extraction
- Conduct Data Clean-Up
- Develop Final Landcover Classifications
- Conduct Internal Quality Control
- Create Consolidated Final Datasets
- Provide draft deliveries by Deliverable Area
- Conduct Corrective Actions based on Quality Control Results
- Participate in project status and deliverable review meetings

The remainder of this section describes the specific project methodology WorldView will implement for the completion of VGIN's project.

2.1 Land Cover Data Development Specifications

The Land Cover database will be developed using Textron Systems Feature Analyst software, which is a third party extension to Esri's ArcGIS Desktop software. Feature Analyst employs a machine learning approach to automated feature extraction which learns to find features like hydrology, vegetation and other land cover features based on user-specified examples (training sets). The software will capture a consistent set of features from the latest Virginia Base Mapping Program (VBMP) aerial imagery in a vector and raster formats, for the entire Commonwealth. Existing vector data sources will be used as "training" data, or as primary source materials for specific classifications. This method will allow Imagery Analysts to control the feature extraction process, rather than using hard-coded classification rules or being reliant on the variability of a "heads-up" approach. The result will be more accurate and provide consistent data development, creating a fully repeatable workflow process.

WorldView Solution's Imagery Analysts will delineate a wide range of land cover data types using a combination of automated, manual, well documented and process-driven data development techniques. Based on previous experience with feature extraction projects, 12 final classifications will be developed for the land cover product. Additionally, there will be a subclassification attribute that allows users to identify underlying extractions of forest, turf, and hydro where wetland features from external datasets were introduced. The following table lists the final first and second order revised Anderson classifications as part of the project:

Classification Categories	Land Cover		Minimum Mapping Unit	Resolution	Accuracy
	Herbaceous	Turf Grass	Less than 2 acres with land use exceptions	1 Meter	85%
	Impervious	Extracted Buildings, driveways, parking lots, roads ,etc	Match resolution	1 Meter	95%
		External Local & Statewide Impervious data	Road centerline dependent	1 Meter	95%
	Forest	Forest	1 acre w/ min width restrictions	1 Meter	95%
		Tree	Less than 1 acre	1 Meter	85%
		Harvested/Disturbed Forest	1 acre w/ min width restrictions	1 Meter	85%
	Scrub/Shrub	Scrub/Shrub	1 acre w/ min width restrictions	1 Meter	85%
	Agriculture	Cropland	1 acre w/ min width restrictions	1 Meter	85%
		Pastureland	1 acre w/ min width restrictions	1 Meter	85%
	Wetlands	NWI/Other	As defined by NWI and TMI	1 Meter	85%
	Barren	Barren	Higher than the resolution	1 Meter	85%
	Water	Water	Higher than the resolution	1 Meter	95%

Table 1: Land Cover Classifications and Project Accuracy

2.1.1 Minimum Mapping Unit

As per the land classification table above, the minimum mapping units for each classification type will depend on the source data or the resolution of the source raster imagery. The minimum mapping unit will be finalized for each classification once source material compilation has been completed.

2.1.2 Resolution

The resolution for all deliverables will be 1 meter for each classification type.

2.1.3 Accuracy

The baseline spatial and classification accuracy of the data deliverables will be targeted at 85%. For many classification categories, a level of 95% accuracy can be achieved. WorldView has targeted this higher level of accuracy for specific classification categories. In the classification breakdown in Table 1, the accuracy targets for each classification category, 85% or 95%, are provided. Accuracy of the dataset will be determined by an independent QA/QC effort conducted by a separate vendor.

2.2 Land Cover Data Development Technical Approach

An overview of the technical workflows, processes and approach for the development of the statewide Land Cover dataset project is provided below.

2.2.1 Compile Source Data

Available source data will be compiled for the project from local government, regional, state and federal data sources. The following data sources are available, but not limited to, for the compilation of Feature Analyst training data creation, manual classification/reclassification and QA/QC:

- Wetlands (National Wetlands Inventory data, Tidal Marsh Inventory)
- Hydrography (National Hydrography Dataset - NHD)
- US Census Urban Areas (2010)
- NAIP Imagery
- DCR Statewide Agricultural Land Use (developed by WorldView in 2014)
- DCR Agricultural BMP (Latest - 2013)
- Statewide Forestry Dataset (developed by the Virginia Department of Forestry in 2005)
- Statewide Timber Permitting dataset (developed by the Virginia Department of Forestry)
- Statewide Land Use Dataset (developed by the Virginia Department of Forestry in 2005)
- Statewide LiDAR Dataset (VGIN 2015)
- VGIN VBMP Othophotography (2011/2013/2014)
- VGIN Digital Terrain Model (DTM) (2011/2013)
- VDMME Mining Permits Data
- Hampton Roads Land Cover (developed by the Hampton Roads Planning District Commission in 2012)
- Rivanna River Watershed Land Use / Land Cover (developed by WorldView in 2011)
- Locality Impervious Basemap Data (various local government sources)
- Hanover County Land Use / Land Cover (developed by WorldView 2012)
- Accomack County Land Use (developed by WorldView in 2009)
- FRA Virginia railroad dataset (2014)

2.2.2 Pilot Project

The pilot project areas have been established to extract particular classifications from particular Hydrologic Units in various localities across the state. Pilot areas were chosen to represent some of the major land use classifications. Hydrologic Units were chosen based on their geographical location and land use/land cover characteristics. Each pilot area will have its own Feature Analyst training sets created and extraction performed. This pilot project approach will provide a representative sample of the feature types expected for both the feature extraction and impervious surface data development portions from different regions within the state. The pilot project areas and feature extraction are as follows:

Classification	Locality	Hydrologic Unit
Mudflats	Accomack	AO08
Barren (Beach)	Accomack	AO08
Turf Grass	Fairfax	PL22
Forest	Fairfax	PL22
Tree	Fairfax	PL22
Barren (extractive)	Wise	TP01
Disturbed Forest	Buckingham	JM52
Cropland	Mecklenburg	RL11
Pasture	Mecklenburg	RL11

Table 2: Pilot Project Localities and Classifications

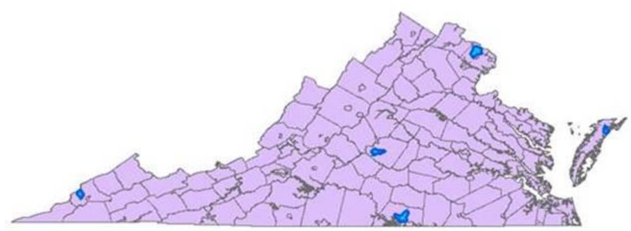


Figure 1: Pilot Project Localities and Hydrologic Units

WorldView will develop a set of vegetation and impervious surface datasets for all pilot areas and will review these deliveries with project partners. Once the pilot project delivery is approved by project partners, WorldView's project team will commence with development of a Draft Pilot Project Delivery. This delivery will provide an opportunity for all of the project partners to evaluate the execution of project products and will include drafts of all deliverables in appropriate formats, along with accompanying documentation, and a report of any outstanding discrepancies that require action. WorldView will work closely with project partners to develop recommendations for resolving discrepancies. After resolving any reported issues, WorldView team members will review feedback, communicate intended resolutions to additional discrepancies, and integrate the resulting changes.

After all discrepancies have been resolved to the satisfaction of the project partners, WorldView will provide the project partners with the Final Pilot Project Delivery. This will include all deliverables created during the Pilot and Draft phases and final copies of any documentation developed for the project.

2.2.3 Develop Deliverable Areas

As described in the next few sections, for land cover feature extraction using Feature Analyst, input bands provide spectral data, input representations provide spatial data, and learning algorithms provide the mathematical calculations that tie it all together. The final parameter that must be set prior to executing any analysis is the extraction area, which is defined by the extent of a reference layer. This will set the geographical bounds as to which imagery will be processed for feature extraction in that learning session. Due to the volume and complexity of the data that is analyzed and returned, it is helpful to define discrete job areas from which it is possible to break analysis into more manageable pieces, rather than run analysis on very large study areas. The output from these areas can then be combined to encompass the full land cover classification.

2.2.3.1 Extraction Regions

The entire state will be divided into sub-regions for classification based on a combination of VBMP 2013/2014/2015 flight data and additional spectral variation identified by WorldView's Imagery Analysts. The following fluctuations in spectral output have assisted in defining such boundaries as follows:

- **Year of imagery collection ranges between 2013 and 2015**. Spectral variation creates the necessity to break these two areas apart. Separate training samples will need to be developed for each of these regions
    - 2014 areas represent a small portion of three counties within the tiled imagery that was missed in the 2013 flight
    - Area in purple is 2013, with western areas flown in 2015:

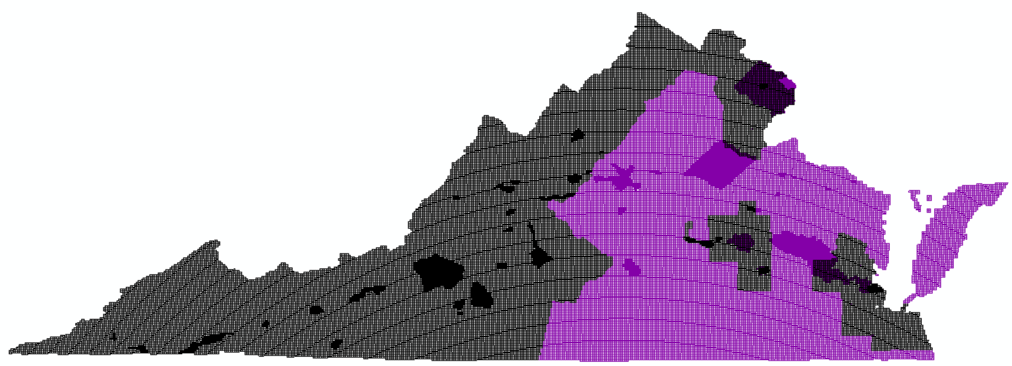


Figure 2: VBMP 2011 and 2013 Imagery Collection Areas

    - The fly zones that were broken apart by year loosely follow Virginia's main physical regions as depicted below:

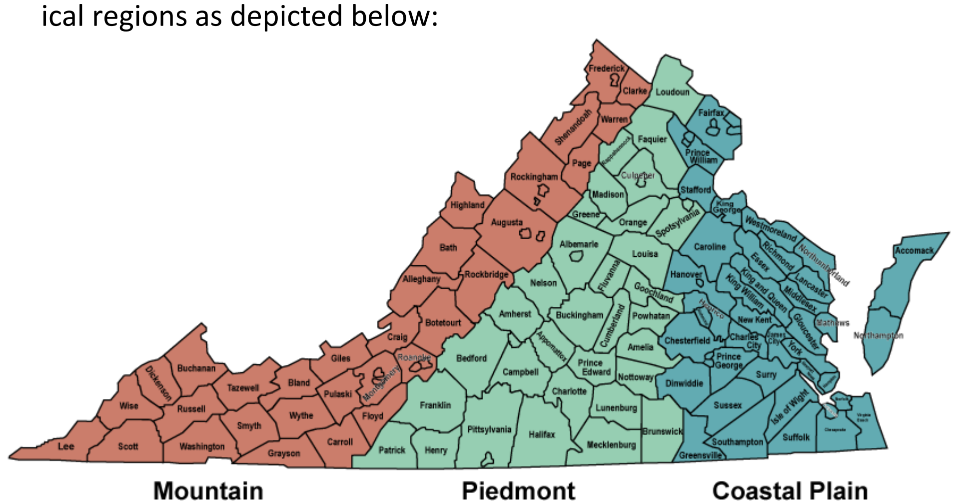


Figure 3: Virginia's Physical Regions

- **Northern versus southern regional hue variation**. The tiles produced in the 2013/2014/2015 VBMP Imagery have been labeled as either North or South, coordinating with the NAD 1983 Virginia State Plane North FIPS 4501 (US Feet) and the NAD 1983 Virginia State Plane South FIPS 4501 (US Feet) coordinate systems , respectively. Spectral variation creates the necessity to break these two areas apart. Separate training samples will need to be developed for each of these regions.
    - The area highlighted below represents the Northern tiles that will need to be subdivided from the first distinction between year:

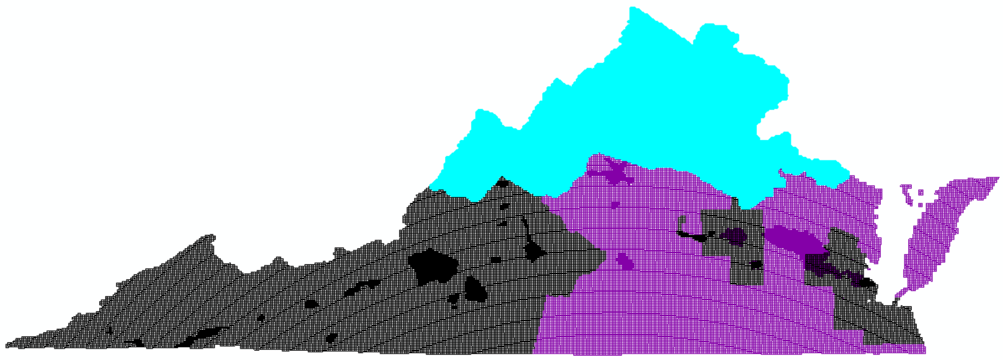


Figure 4: NAD 1983 Virginia State Plane North FIPS 4501 (US Feet) Area

- **Differing resolution (1-foot, 6-inch, and 3-inch tiles)**. There are scattered areas throughout the state that have captured higher resolution images than the typical 1 foot pixel tiles. These areas have distinctly varied hues from the surrounding tiles, and will need to have their own training samples and learning extractions ran.

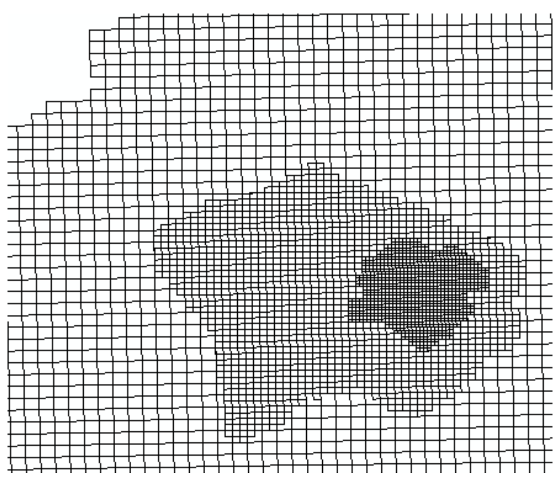


Figure 5: Grid example of differing VBMP Tile pixel resolution

- **Additional spectral variation (hue and saturation)**. Additional spectral variation exists between areas that were not initially identified. These areas are usually very flat boundaries across the state that can easily be distinguished Additional boundaries will be created between remaining areas of varying hues and saturation, further subdividing the previous regions.

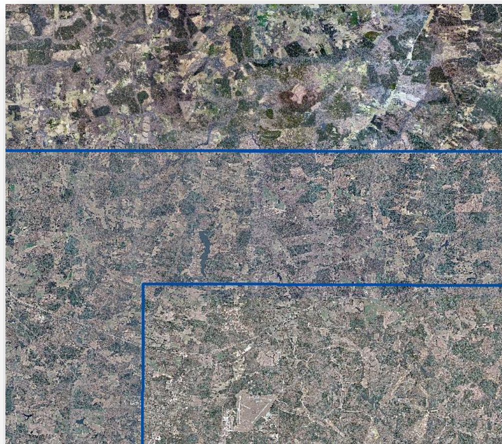


Figure 6: Example of additional spectral variation (hue and saturation)

- **Geographic feature variation**. It is necessary to additionally divide regions with distinct geographical characteristics. As training sets are developed within a region to extract features, such features and band compositions may exist in one geographical region that are not present in another.
    - For example, in a mountainous region, forested training samples will have darker shadowed areas where elevation change occurs, as well as distinctive patterns in response to weather conditions as pressure change occurs in these areas. To avoid misclassification in the land beyond such features, many more training sets are needed to cover the additional forest composition, but would not want to include any of the previous training sets that would not be found in this area. For regions that appear to have distinct elements, such as high mountainous features, vast pastureland, wet versus dry agricultural areas, etc., each would need to have individual sets of extraction training samples.
    - In the depiction below, this region was further subdivided into 3 zones, where changes in elevation, land use, and forest types occur:

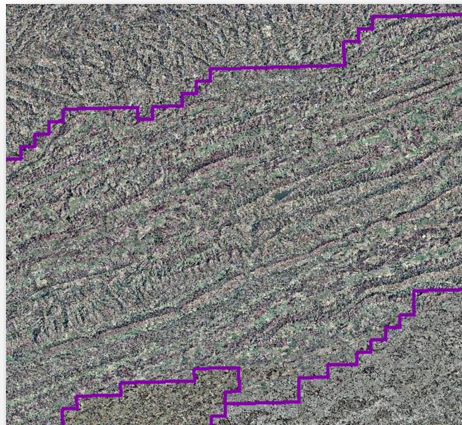


Figure 7: Example of Geographic Region variation

2.2.3.2 Deliverable Areas

Six Deliverable Areas were developed for this project, based on the previously divided regions (classification areas), the established pilot areas, and the request to develop the Chesapeake Bay watershed counties before the remainder of the state. The regional extraction boundaries developed in the previous section were further adjusted to divide the counties intersecting the Chesapeake Bay watershed area from the remaining watershed areas of the state.

Once the feature analyst extraction boundaries were finalized based on deliverable areas, both the Chesapeake Bay watershed and the remainder of the state were broken into three deliverable sets. By partitioning the regions into a total of six deliverable areas, progress tracking and extraction tasks will be managed more efficiently. The final deliverable areas were designed to encompass relatively even coverage, while following the developed feature analyst extraction regions. The six delivery areas are as follows:

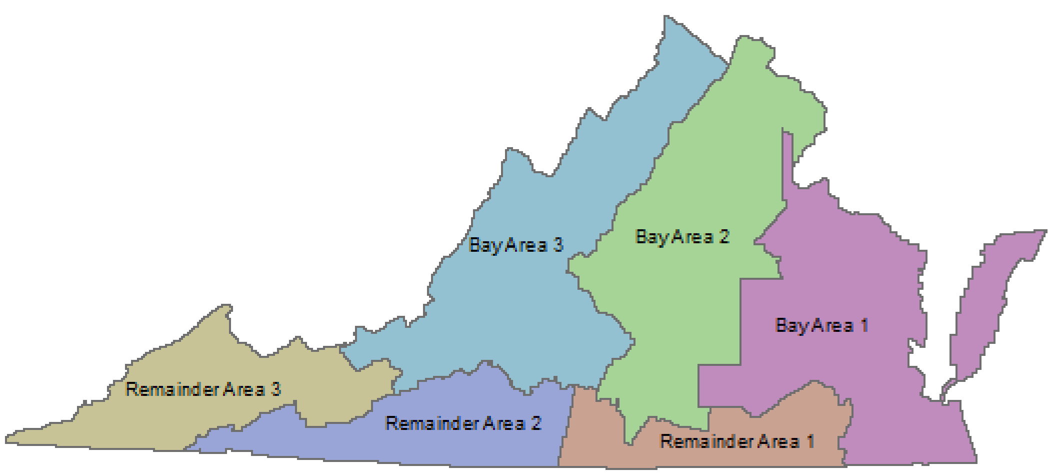


Figure 8: Project Delivery Areas

The calculated size of each deliverable area is as follows:

Delivery Area	Square Miles
Bay Area 1	9,633
Bay Area 2	9,757
Bay Area 3	9,775
Remainder Area 1	3,399
Remainder Area 2	4,570
Remainder Area 3	5,125

Table 3: Project Delivery Size in Square Miles

2.2.4 Prepare Imagery

The first step in organizing the imagery into the developed regions is to add tiles within a region to a mosaic dataset. A series of file geodatabases will be developed, organized according to their collection date and geographic region, to house these mosaic datasets. Each file geodatabase will be named based on collection date, geographic region and their color differentiation. Furthermore, there are a number of regions within the same year, geographic region, and color pattern that will receive an underscore and number based on the order they would be processed for land use classification.

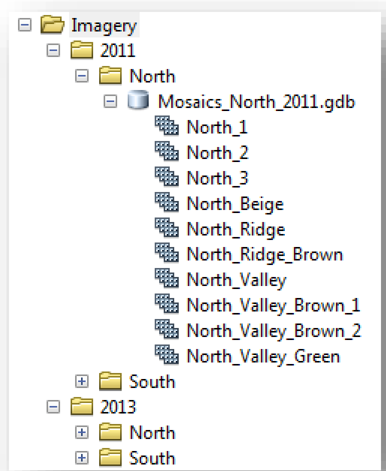


Figure 9: Imagery mosaic dataset organizational file structure
(Originally 2011 data was compiled for the western portion of the state, until 2015 became available)

Before extraction can begin on the raster imagery data, all tiles must have a consistent resolution across the state. The raw data varies between 1 foot, 6 inch, and 3 inch resolutions, which at such a high precision would involve extremely lengthy processing time when extracting land use classifications. Due to the land cover classes having a desired 1 meter resolution, the decision was made to resample all imagery to 1 meter, reducing processing time and maintaining the output resolution. The resampling geoprocessing tool will be executed within the mosaic dataset, causing the new TIFF images to reflect the current projection. Bilinear Interpolation resampling technique will be selected to create a new continuous image dataset.

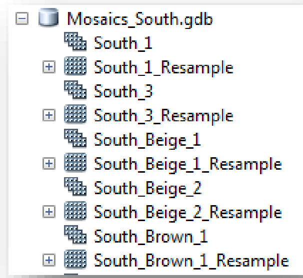


Figure 10: Imagery mosaic dataset resample file structure

2.2.5 Feature Analyst & Final Cleanup Workflow

Initial extraction will be conducted through Feature Analyst, an extension to Esri's software suite. The tools within Feature Analyst streamline the geoprocessing tasks related to extracting land cover features from high-resolution aerial imagery. The object-oriented software utilizes the spatial context, as well as spectral and pattern data, through the creation of digitized training datasets and user-defined learning parameters. Upon initial extraction, a number of built-in tools are available for further data cleanup. In preparation for the delivery of statewide land cover, image extraction will be carried out prior to the use of external data sources, and then subjected to a series of automated cleanup scripts and manual editing. These steps are detailed in the following sections.

2.2.5.1 Create Training Data

A series of training data sets will be created, using field and "screen" verified data samples, for each of the land cover classification schemes. Training data is used by Feature Analyst to "learn" the band composition associated with each classification and apply that knowledge to extract full coverage vector features over a defined raster image. Training data are created as polygon shape-files, and will be represented as a compilation of vector features for each land cover type; most will be heads-up digitized by Imagery Analysts, supplemented by external features from existing localities' datasets. The number of samples that can be directly input into the training sets for land cover extraction will depend on the availability of existing data, and knowledge of the project area. Separate training data layers will be created for each individual mosaic dataset.

Figure 11: Example of head-up digitized training dataset polygons

Typically, training sets work best with a discrete number of features that are representative of the overall frequency and size of features. Training sets will be refined and revised on an as needed basis in response to the accuracy of results emerging from data interpretation tests of the evolving feature extraction learning parameters. However, a minimum of 20 samples will be collected per class within each tiled boundary, with additional samples depending on the frequency of that particular class.

A variety of factors will be employed when generating training samples for feature extraction. In order to increase accuracy of initial land cover vector output, the following factors employed will include but are not limited to:

- Full spectral variety included in sample features

Figure 12: Example of spectral variety in turf features

- Varied orientation of polygon features representative of ground coverage

Figure 13: Example of varied orientation of impervious features

- Samples digitized to encompass entire feature and distinguish edge of classification change

Figure 14: Example of distinguished edge of classification change included in training datasets

The individual land cover layers will then be represented in a multi-class input layer that combines the training sets into a single feature class. Attribution will delineate subtypes and symbology for each of the desired land cover classes. This final multi-class input layer will be the input to the Supervised Learning feature extraction.

2.2.5.2 Set up Learning Parameters

The initial vector output from the Supervised Learning method will be dependent on the Input Representation parameters set up for extraction. Changes to the pattern and width of raster image cells that Feature Analyst will analyze for each cell's classification will lead to diversity in outputs. The various outputs will be evaluated to identify the ideal classification pattern in each working area.

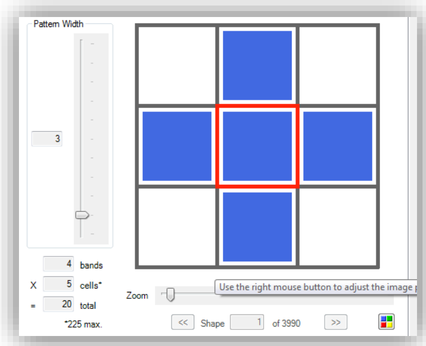


Figure 15: Example of Input Representation parameters for feature extraction

Other parameters that will modify results include applying a histogram stretch to the input bands and adjusting band type. Additional options can be applied to the dataset to aggregate small regions, remove large regions, and smooth features, based on user input to size and conversion factor. Results will be optimized on a per region basis, while taking advantage of some of the functions in the Conduct Supervised Feature Extraction step below on a per classification basis. The best results were collected using the Bulls Eye 2 Input Representation with a Pattern Width of 15. Aggregation was applied to certain features, such as Ag fields having a minimum pixel size of 4047 square meters, and masking the locality impervious datasets.

2.2.5.3 Conduct Supervised Feature Extraction

Once training data is developed, learning parameters set, and extraction area defined, supervised feature extraction analysis is kicked-off, and the Feature Analyst software runs independently to analyze and extract features from the base imagery, based on the detailed training datasets. Once extraction is completed, Imagery Analysts will review individual outputs to assess the overall quality of the land cover extraction. Due to the size limitations of larger features, the multi-input extractions were developed as raster output, while the individual classes were extracted as vector..

Complementing the output from the original training datasets, new learning parameters will subsequently be designed and configured from discrepancies found in the first output dataset. The derived multi-class input layer will be broken into individual land cover classes for further processing to each feature layer as necessary. This process will be refined by Imagery Analysts and project stakeholders, through application of Feature Analyst post processing and hierarchical learning functions. The Feature Analyst Learner will rely on a series of learning passes (feature extractions) to determine whether or not image pixels represent the target features identified in each training set. Feature Analyst functions to be utilized will include:

- **Clutter Removal** - Remove extraneous features from the feature extraction output, within the minimum mapping unit parameters.
    - Heads-up digitizing/selecting correct features
    - Heads-up digitizing/selecting incorrect features

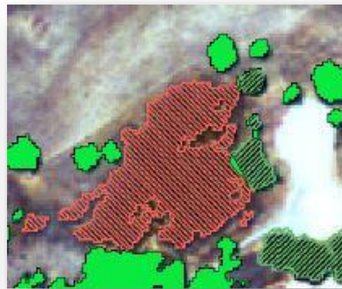


Figure 16: Image depicting Feature Analyst Clutter Removal function

- **Adding Missed Features –** Refine results that have already had majority of clutter removed, to further improve learning.
  - Digitizing new training samples to include in dataset

Figure 17: Image depicting Add Missed Features function

After each function is completed, a final supervised learning pass (feature extraction) will be executed. A combined Input layer from the most accurate of each class extraction will be created and Imagery Analysts will evaluate the accuracy within each layer to create a hierarchical structure to resolve overlapping regions.

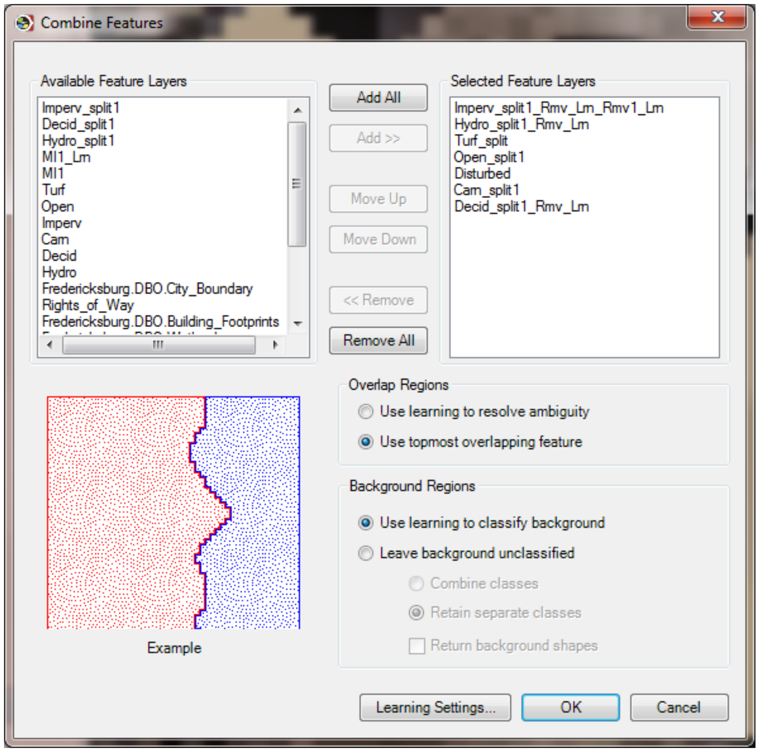


Figure 18: Feature Analyst Combine Features tool with hierarchical structure for overlapping regions

The learning parameter definition and refinement process is iterative and is typically repeated numerous times during the project lifecycle. Once the Analyst is sufficiently satisfied with feature extraction results, the dataset will be passed to the data clean-up stage.

2.2.5.4 Conduct Data Clean-Up

After feature extraction using Feature Analyst, a variety of techniques and geoprocessing functions will be configured and automated to clean up artifacts and errors known to be made in the initial learning output by Feature Analyst. Initially, a series of tools will be executed against the output to improve the dataset and classifications. In some cases this will involve splitting the multi-class polygon layer into separate or distinct subsets of classification upon which to perform clean-up activities.

The Feature Analyst geoprocessing tools that will be used to automate the clean-up of the full output dataset include, but are not limited to:

- **Aggregate features** – Aggregation of features that meet the same criteria but are improperly segmented by other features or classification types.
- **Smooth features** – Within the resolution and minimum mapping units, smooth features to product better contrast between feature classifications.
- **Feature reclassification** – Where applicable, reclassify features to meet refined feature classification types.

The Feature Analyst geoprocessing tools that may be performed on a per class basis include:

- **Reshape features** – Fill holes/gaps in features, merge features with a newly digitized connection

- **Square Up features** – Best for buildings and other impervious features that have distinctly square geometry
- **Feature Simplification** – Export extracted features to a new shapefile with additional specifications as needed
  - Minimum vertex spacing
  - Area Attribution
  - Eliminate shapes by area
  - Eliminate shapes by attribute

Following the use of cleanup tools within the software to improve upon initial results, a number of custom scripts will be created and applied at various levels, paired with manual stages of cleanup, to meet accuracy standards on the various classifications. While it is possible to produce a defensible land cover product based purely on automated feature extraction and clean-up processes, it is anticipated that a significant amount of manual data clean-up will need to be performed as part of the project to differentiate some of the requested classifications that cannot be identified based on spectral signature alone, such as Pastures vs TurfGrass, or yards separated from a Pasture by a fenceline. This will be accomplished through visual inspection against statewide imagery.

Scripted methods for cleaning up the data will include reclassification of certain land use types due to total area of independent vector features within a class, proximity of one class's features to another, and identification of typical class confusion. The methodology behind script automation refines further as new regions are developed that introduce unique features, such as forest shadows in the mountains. A distinct script will be developed to automate cleanup against the subclassified regions, as these areas with wetland characteristics typically reduce to only include forest, turf, and hydro from the initial feature extraction.

2.2.5.5 Develop Final Classifications

At this point in the extraction process, where Feature Analyst classification output has been cleaned up using automated processes and manual editing, the 12 deliverable classes will be finalized. In the previous step, many classes that will not be listed in the final set of land cover features were created to assist in image extraction, such as Forest Shadow. With the vector output layers defining quality boundaries between different feature types, Analysts will engage the local impervious, wetland, and other available datasets to erase and append into the final vector results, as well as amend and merge the broken out classes to develop the final delivery classifications. This is where the subclassification occurs within wetland features, and these features receive automated cleanup.

Additional post-processing steps taken to reach the final output include running Esri geoprocessing tools to eliminate outliers, checking for data gaps due to the processing of very large and complex features, as well as delineating impervious features from outside datasets into their own class.

2.2.6 Corrective Actions

Upon delivery of a draft version of the land cover product, each classification's accuracy will be tested by an independent QA/QC effort, where results will be shared and final dataset revisions completed. The period of corrective actions will allow time for any necessary changes to be made to the final product and methodologies.

2.2.6.1 QC Vendor Analysis

A combination of image analysis and photointerpretation will be used to select random samples from the data. These samples will be buffered by 25 sq meters to ensure equal representation of each point's underlying feature, with some buffered points being manually delineated. Points will be labeled based on the land cover output, then referenced against the source imagery in order to more accurately represent the landscape. A minimum point count of 50 is being targeted per classification in each delivery area. The final number of points in each class will vary based on that class's proportion of coverage compared to the overall proportion of area determined in the land cover product, with the highest proportion of features such as Forest having close to 500 sample points.

The QC vendor will develop a set of confusion matrices to compare results on each classification's overall User & Producer Accuracy. The results will take into account fuzzy logic, where certain features may fall into more than one class depending on the photointerpreter. Labeling classes to be delineated as "fuzzy" will be decided by all parties and then released as an individual set of statistics. When the photointerpreters label a point based on the imagery, they will also add additional labels for competing classes. During compilation of the fuzzy matrix, if any labels match that of the land cover, the point is considered correct. The final accuracy results of this product will be shared with all parties involved in the development of the land cover dataset, and a series of additional cleanup steps will be agreed upon based on targeted inaccuracies found.

2.2.6.2 Dataset Corrections

Once QC results are received, a plan of action is developed based on trending misclassifications. Image analysts will get a chance to evaluate the final matrices with the additional feedback from the QC vendor. While locations of sample points will be kept confidential, feedback will include large scale screenshots of where the incorrect point fell in the land cover product. With this information, it can determined as to why the image extraction failed, and what steps can be completed to rectify the issue. A conclusion may be that not enough sample points were created to best represent a certain feature characteristic, an example including dark water features that resulted in false impervious classifications, leading to improved training sets developed. Another example may find that shadows and other false positives can be rectified by setting size thresholds and reclassifying based on intersecting feature identities. Some outcomes will necessitate reexamining the features manually to correct misclassifications. Similar actions were taken in the creation of the draft product, while this effort assists in improved accuracy and the identification of missed outliers with an additional set of sample point checks.

Allotted time has been set aside after each delivery area to review QC results and make final adjustments to the product. This has allowed for a combination of automated and manual cleanup efforts to be utilized to complete modifications based on the findings from the reports. Upon receipt of QC reports for each draft delivery area, improvements will be made to the development process moving forward to subsequent deliveries. Once the first 3 draft deliveries have been developed, they will undergo a final corrective action period that addresses the particular accuracy findings. Development will then begin for the 3 remaining delivery areas, following a similar structure.

2.3 Land Cover Classifications

The following section provides details on the definition of each land cover classification and the workflow that will be implemented to develop each classification type. Land Cover Classifications, data sources and bounding criteria are referenced in Appendix A, Classification Details.

2.3.1 Hydrography

2.3.1.1 Classification Definition

This classification includes all areas of open water; typically 25 percent or greater pixel cover of water, and all areas characterized by perennial cover of ice/snow as defined by the EPA. Includes drainage network and basins such as rivers, streams, lakes, canals, waterways, reservoirs, ponds, bays, estuaries, and ocean as defined by the NHD. Only features greater than 1 acre in size will remain in this classification.

2.3.1.2 Workflow Methodology

A Hydrography feature analyst layer will be developed initially, while it is recognized that the spectral range for these features will also include shadows from trees and buildings, as well as misclassification due to muddy/green waters. Once the hydrography layer is established, manual cleanup efforts will improve accuracy of features:

- **Hydrography –** These are polygonal features representing open water features. Existing National Hydrology Dataset (NHD) data will be delivered as an overlay to the full dataset. This overlay will include flow polylines that will be buffered based on a general 15ft representation of perennial stream features.

Figure 19: Example of NHD data overlay

The main use of the Feature Analyst hydrography layer is to assist in defining other classifications during initial extraction, where the misclassified features can still be easily interpreted from the imagery and cleaned up to reveal most hydrology features. There will be features caught in the image extraction for private land that will complement the hydrological data overlay, as well as features in the overlay that cannot be visible from the image, such as streamlines within a forest. From the hydrography extracted in the full land cover, as well as the overlay polygons, only those features greater than 1 acre in size will remain in the output.

The Eliminate tool will be ran against the Feature Analyst hydrography output to reclassify incorrect and smaller features of this type to the closest competing feature classification of the greatest size. This will ensure that shadows from buildings will dissolve into the surrounding land features, while anomalies of green and brown land that may have been misclassified as water be corrected to forest or turf. The minimum area criteria will decide which extracted features stay in the dataset.

VGIN DTM Data will also be analyzed for capability in filtering of potential water surfaces using a terrain deviation parameter (e.g., filtering features with a deviation from the terrain of <1 meter).

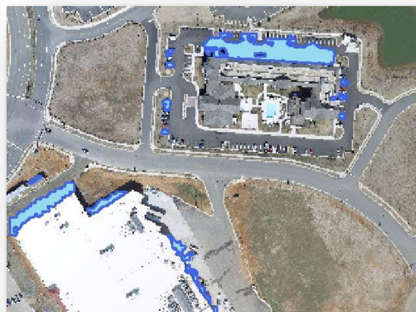


Figure 20: Example of misclassification of hydrology features

2.3.2 Cropland

2.3.2.1 Classification Definition

This classification includes areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber, or is maintained in developed settings for specific purposes as defined by the EPA. When the production of agricultural crops is not hindered by wetland conditions, such cropland should be included in the Agricultural category; when lands produce economic commodities as a function of their wild state such as wild rice, cattails, or certain forest products 'commonly associated with wetland, however, they should be included in the Wetland category as defined by James Anderson, USGS. Examples include row crops, small grain, fallow (tilled with sparse vegetative cover), feeding operations, orchards, groves, vineyards, nurseries, and other horticultural areas. Any grasses or managed turf that fall into this description, or otherwise cannot be categorized as pastureland will be included here if the land is less than 1 acre in size.

2.3.2.2 Workflow Methodology

Cropland and Pastureland will start as a set of training samples that simply define those non-forested areas of flat land into large classifications including spectral variation between yellows, greens, and browns. Any attempt to distinguish between what is actually agricultural, turf, etc. within the image extraction process ends up as blended results. Buffered road centerlines are used as a mask to make sure fields get cut up appropriately. This classification will just be “Agriculture” and will be developed using Feature Analyst independently of the multi-class land cover extraction.

With the color variation creating bounded features, the DCR agricultural points and polygons will be utilized to identify all of those polygon features that fall into the cropland class. The DCR spatial data will be overlaid on top of the feature analyst output and Imagery Analysts will reclassify features as needed to this new class. There will also be some manual digitizing and editing where areas identified in the DCR dataset were not extracted into individual polygons, or did in fact encompass multiple areas that need to be cut into individual polygons.

2.3.3 Pastureland

2.3.3.1 Classification Definition

This classification includes areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops as defined by the EPA. The land may be used only for pasture in rotation with crops, or more or less permanently used for this purpose; while the condition of the land may not match exactly with the time the imagery was taken, this can be used as a guide as defined by James Anderson, USGS. Any grasses or managed turf that fall into this description, or otherwise cannot be categorized as cropland or recreational will be included here if the land is greater than 1 acre in size.

2.3.3.2 Workflow Methodology

A similar process described in the above section for Cropland will be used to determine Pastureland. The DCR point data will be the resource for reclassifying features that fall into the Pastureland class. Remote sensing point data will also assist in defining areas that fall into the Pasture classification. This process will take place simultaneously with Cropland classification, and will involve similar manual data clean up, as large public and recreational fields (airports, schools, etc) will need to be removed and classified as TurfGrass. An additional post processing step will be applied to compare the National Agricultural Statistical Survey (NASS) data for Pastures against what is extracted as Cropland, due to many of the fields being indeterminate from the imagery alone. Where imagery analysts are able to determine an Agricultural field exists, and the field is 75% covered by NASS Pasture, the feature will be classified as Pasture.

2.3.4 Turf Grass

2.3.4.1 Classification Definition

This classification includes vegetation (primarily grasses) planted in developed settings for erosion control or aesthetic purposes, as well as natural herbaceous vegetation and undeveloped land, including upland grasses and forbs, as defined by the EPA. Examples include but are not limited to recreational areas, lawns, and vacant lands. Any grasses or managed turf that fall into this description will be included if the land is less than 1 acre in size, or visually determined to be recreational form the imagery.

2.3.4.2 Workflow Methodology

TurfGrass will start as a set of training samples that define those non-forested and non-agricultural areas of flat land into large classifications including spectral variation between yellows, greens, and browns. Any attempt to distinguish between what is actually agricultural, turf, etc. within the image extraction process ends up as blended results, so although this class will also capture agricultural land, these areas will be removed later on as they are processed first. Areas that are extracted in this classification that are greater than or equal to 2 acres will, and are within parcels greater than 3 acres, will be reevaluated as possible reclassification into Pasture. For those areas where parcel data is unavailable, all features meeting the size threshold will be reviewed. There will be a stage of manual cleanup for falsely identified features.

Figure 21: Example training samples of original spectral hue variation (green, yellow, brown)

Figure 22: Examples of Turf Grass are depicted in Yellow

2.3.5 Barren

2.3.5.1 Classification Definition

This classification includes areas with little or no vegetation characterized by bedrock, desert pavement, beach and other sand/rock/clay accumulations, as well as areas of extractive mining activities with significant surface expression as defined by the EPA. Example features include but are not limited to beaches, volcanic material, slides, quarries, strip mines, and gravel pits. Vegetation, if present, would be more widely spaced than that of the scrub/shrub category, and would have limited ability to support life (such as clearing due natural fire, flood, etc.). When the land is in a transitional state where barren characteristics may be inferred, but there are no sizable areas that are purely barren, these features will be classified as Disturbed Forest.

2.3.5.2 Workflow Methodology

This classification will be developed independently using Feature Analyst and a set of large training samples over areas of mining, construction, beach, etc. While Barren features do not fall into the same category as impervious, many of the physical features share the same spectral range. The major step here is breaking Barren into its correct feature classification. This will involve a manual analysis of the outputs for Barren against the statewide imagery, removing anything falsely classified. Impervious datasets from localities and the state will be used as a mask to reduce the amount of incorrect features needing to be deleted. Analysts will manually reclassify those areas that did not correctly fall into Barren in later steps.

Any available local data will also be used to identify features falling into this category, along with statewide mining site datasets available through VDMME. Feature extraction will be analyzed against these datasets for reclassification or heads-up digitizing where features were missed.

VGIN LiDAR data will be analyzed for use in filtering of potential barren land classification using a terrain deviation parameter (e.g., filtering features with a deviation from the terrain of <2 meters).

2.3.6 Impervious (Extracted and External)

2.3.6.1 Classification Definition

This classification includes areas characterized by a high percentage of constructed materials such as asphalt and concrete, buildings and parking lots, and infrastructure such as roads and railroads as defined by the EPA.

2.3.6.2 Workflow Methodology

As mentioned previously, Impervious and Building layers were originally created separately in order to utilize the Feature Analyst Building Toolkit to extract more precise footprints for localities that did not already maintain them. These two feature classifications will be combined grouping all impervious features together.

The next step to developing the impervious features will be the input of existing vector data sources. Feature Analyst impervious surface features will be supplemented with available local, regional and state basemap data by erasing and appending these datasets to the extracted output. This will ensure that the land cover data represent impervious surfaces regardless of overhanging tree canopy. Where vector features provide a more accurate representation of impervious surfaces for any given feature, we will defer to this source. Where they are less accurate or not available, we will defer to the spectral classification method for the impervious feature. Features to collect include the following:

- **Buildings –** These are features representing residential and commercial building footprints. These features will be generally representative of actual ground feature dimensions, and will be the latest combined statewide feature class provided by VGIN for the majority of localities. Existing data will be used to aid in the identification of structure locations, supplemented by actual feature locations and geometry automatically extracted from aerial photography as well. Where there are localities that do not have building footprints already available, WorldView will utilize the Feature Analyst to directly extract from the latest available (anticipated to be either 2013 / 2015 or 2011 / 2013) VBMP aerial photography.

Figure 23: Example of building footprint data

- **Roads –** These are features representing automotive thoroughfares. Statewide data are represented as linear roadway centerline features. In order to create a polygonal representation from a centerline, which has length, but no width, a buffer must be created. This will be accomplished by establishing a distance around centerlines to which polygons will be built. The initial problem with this approach is that buffers represent only an estimate of the actual width of the thoroughfare, which may vary significantly from reality. This uncertainty can be compensated for by using supplemental information, such as roadway classification to apply varying buffer distances depending on whether a particular segment is an Interstate, highway, or secondary roadway. Alternately, if available, more specific VDOT attribution such as number of lanes, lane width and hard shoulder width may be incorporated to better model these surfaces. For some road segments, this data is not available, and will need to be reviewed.

Figure 24: Example of buffered road width

- **Ancillary Roads –** These are linear features representing ancillary centerlines. These are linear features that were not considered to be roadway centerlines or streams, but were visible on the aerial photography. These features may be driveways, wide hiking or ATV trails, logging roads, jeep trails, private roadways, or other similar features. As with the road centerlines, these features will be buffered using a measured width that will represent ancillary roadway impervious surfaces.
- **Railroads –** These are features representing locomotive railway centerlines, represented as linear features. These features will be converted to polygonal representations rail bed features through use of a single buffer distance equivalent to the typical rail bed width, which will be agreed upon by the project stakeholders prior to conversion. These features will be clipped and removed where they intersect bridge deck features.

Figure 25: Example of railroads classified as impervious

- **Other Impervious Surface Features –** These are polygonal features representing other potential impervious surfaces (e.g., large parking lots). Any available existing base-mapping data will be used to aid in the identification of these impervious surface locations.

Once the locally maintained features have been converted to polygon shape, erased from the feature analyst output, then merged back in, all extracted Impervious features that do not overlap available state and local impervious data, will be labeled as their own classification. The merged local datasets will become another impervious classification, complementing the feature analyst output, such as where shadows of other features cross into roads.

2.3.7 Forest

2.3.7.1 Classification Definition

This classification includes areas characterized by tree cover of natural or semi-natural woody vegetation as defined by the EPA, greater than an acre in size; this class includes deciduous, evergreen, and mixed foliage types. Any area that is not encompassed by a 1 acre circle will be characterized as Tree (see workflow Appendix).

2.3.7.2 Workflow Methodology

To extract the final Forest classification, we will be merging the various forested Feature Analyst classes. In order for the software to capture all of the various tree types and spectrums in the extraction, a combination of three classes was created:

- Deciduous Forest – This class will pick up all band spectrums for the leaf-off trees and those with browning leaves
- Coniferous Forest – This class will pick up mixed foliage and evergreen trees by detecting green foliage
- Forest Shadow – This class will pick up the darker color bands associated with the shadows produced in more mountainous or hilly forested areas

The combination of these three classes has been shown to produce the greatest accuracy in capturing all tree features from the aerial imagery. When these features are extracted and then merged together, they will exported to raster format and ran through a series of raster calculations that will develop areas that completely contain 1 acre of trees, starting from within the extracted features by "shrinking" the original output and then buffering back out to the extracted boundary. This will exclude long linear stretches of trees that are not in a forest, and only those feature's that fully encompass the buffer will be included in this class.

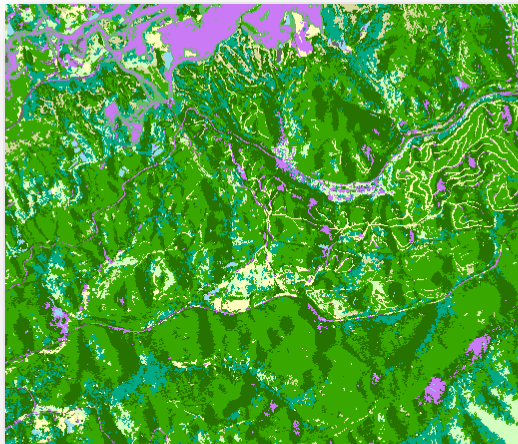


Figure 26: Example of various forest classes that capture trees shadows

2.3.8 Tree

2.3.8.1 Classification Definition

This classification includes areas characterized by tree cover of natural or semi-natural woody vegetation as defined by the EPA, less than or equal to an acre in size; this class includes deciduous, evergreen, and mixed foliage types (see workflow Appendix).

2.3.8.2 Workflow Methodology

A similar process described in the above section for Forest will be used to determine Tree. This process will take place simultaneously with the Forest classification, and will involve reclassifying the features that do not fall within the 1 acre developed raster into this classification.

In highly developed areas, spectral variance is greater in yards, and causes confusion between grass and trees. In identified urbanized areas where this issue arises, Lidar data will be processed into tree polygon features to reclassify all trees extracted in these areas; initially, trees will be reclassified to Turf, then replaced as Tree only where the Lidar polygons overlap.

2.3.9 Harvested/Disturbed Forest

2.3.9.1 Classification Definition

This classification includes areas of forest clear-cut, temporary clearing of vegetation, and other dynamically changing land cover due to land use activities as defined by the EPA. These features should be categorized only where there is 30% canopy cover or less. This can be determined by calculating mean NDVI values for Harvested areas, and only including those that exceeded values between 115 and 120.

2.3.9.2 Workflow Methodology

Following the steps outlined in the above section for classifying Forest, the forest features will then be further subdivided to create the Harvested/Disturbed class.

Harvested areas will be developed independently using Feature Analyst, due to their unique characteristics and size; while this process creates a better extraction than developing Harvested features within a multi-class learning pass, there will still be a manual process of cutting the existing output by reviewing the aerial photography. This is due to the variation in physical appearance for many of these areas. This class is transitional and may include anywhere from a clear-cut lot to fallen trees, or mature trees ready to be cut. However, additional data sources from VDOF will aid in locating the areas to review for extraction.

Figure 27: Examples of transitional harvested/disturbed forest

2.3.10 Scrub/Shrub

2.3.10.1 Classification Definition

This classification can be characterized by natural or semi-natural woody vegetation with aerial stems generally less than 6 meters tall; evergreen and deciduous species of true shrubs, young trees, and those that are small or stunted due to environmental conditions as defined by the EPA. Seeing as LiDAR data was not available for the entire state, and did not develop well-defined areas of shrub, features classified here will include easement fields, stunted tree growth around wetland features, and any additional patches of stunted trees and turf that do not fit into the remaining classifications.

2.3.10.2 Workflow Methodology

Development of scrub / shrub classification will mainly be through manual reclassification methods, with assignment of features that do not meet other classification criteria into this category. Where features displayed in the imagery do not exhibit characteristics of Harvested/Disturbed forest, but are clearly not matured into trees, the polygons will be classified here. VEDP powerline data will assist in locating easements to be added to this classification.

2.3.11 NWI/Other

2.3.11.1 Classification Definition

This classification includes all NWI Woody Wetland areas where forest or shrub land vegetation accounts for 25% to 100% of the cover and the soil or substrate is periodically saturated with or covered with water as defined by the EPA. This classification also includes all NWI Emergent Wetland features where perennial herbaceous vegetation accounts for 25% to 100% of the cover and the soil or substrate is periodically saturated with or covered with water as defined by the EPA.

2.3.11.2 Workflow Methodology

There were no Feature Analyst training sets for this land cover classification, as field verification would be necessary to distinguish these areas geographically. Therefore, data for this class will be derived from the existing wetlands feature classes available by the National Wetlands Inventory (NWI) and Tidal Marsh Inventory (TMI), with an underlying extraction retained as a subclassification field attribute. These wetland datasets are derived by systems and classes based on vegetation, substrate, and hydrologic conditions. There are specific features associated with Scrub/shrub and Forested Wetland within these datasets that will be combined to fill this classification.

In order to reclassify the Feature Analyst output to include Emergent & Woody Wetlands as part of the final classifications, analysts will run automated identity scripts that will cut the Feature Analyst output dataset to the boundaries of the NWI/TMI data and input as the final NWI/Other classification. Additionally, automated scripts will create a subclass field that retains the original extracted output from the multi-input learning, attributing these intersecting wetland features as Automated Turf, Forest, and Hydro. Having this additional subclass available within the wetland boundary is necessary because the wetland data is received from external sources, and allows users to see what extracted land cover is in their area, without the identification of wetland features. This subclass of data will not undergo further QC upon completion of the original extraction, and therefore will be titled and treated as automated. This should identify to users that it does not meet the same quality and standards as the rest of the product, but resembles what classes are identified solely from the imagery.

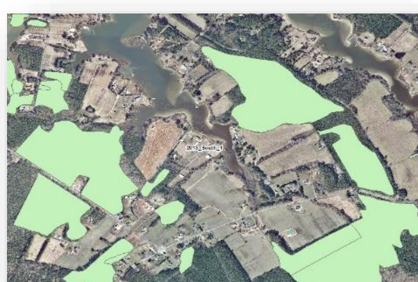


Figure 28: Example of Woody Wetland features from NWI dataset

Figure 29: Example of Emergent Wetland features from NWI dataset

2.4 Internal Quality Assurance/Quality Control

Working closely with VGIN and its partners, WorldView will employ a set of quality assurance and quality control procedures, using randomly selected accuracy assessment points, to review land cover classification products both automatically and manually. This data comparison will be a result of the output against the imagery, as well as a separate accuracy check from collected local datasets.

Imagery Analysts will review the vector data output classifications against 1 meter imagery to locate anomalous features and identify possible changes to learning parameters within that class.

If necessary, sampling methods and approach will be adjusted so that the draft and final products meet the agreed upon level of accuracy for the product. The classification accuracy of the data deliverables will be 85-95%.

Quality assurance will involve using randomly selected accuracy assessment points to check coverage visually, as well as an overall visual QA across the state, with additional data layers available to aid in quality checks. These include Land Use/Land Cover datasets developed by the Virginia Department of Forestry, the Chesapeake Bay Program, and the National Agricultural Statistics Service, as well as a number of other datasets provided on the state or local level identified as including characteristics associated with the developing class. So far these include the Virginia Department of Mines Minerals and Energy mining features. As more datasets are identified, they will be incorporated into the final process for developing quality control.

Class	QA/QC Data Source	Visual QA	Manipulation
Turf Grass	VBMP	Y	
Tree	VBMP, VDOF LULC	Y	
Forest	VBMP, VDOF LULC	Y	
Harvested/Disturbed Forest	VDOF Timber Harvest Dataset		Y
Scrub/Shrub	Easements and VBMP		Y
NWI/Other	NWI, TMI	Y	
Pasture	DCR Agricultural points		Y
Cropland	DCR Agricultural points		Y

Impervious (Extracted)	VBMP	Y	
Impervious (External)	Local Impervious, VGIN RCL & Buildings	Y	
Barren	VDMME, TBD		Y
Water	NHD, VGIN DTM	Y	

Table 4: Internal QA/QC Sources and Processes

The finalized land cover data will be merged into single feature class and a single raster output that contains classifications for each land cover type. This feature class and the raster output will be delivered in one meter formats, for each delivery area.

3. Project Management Plan

The project management goal for this project is to provide the tools and techniques that facilitate the entire project team to organize its work to meet VGIN's project goals, schedule, and cost constraints. The task of proper project management and oversight is one that WorldView takes very seriously.

3.1 Project Milestones, Deliverables and Schedule

The following table identifies milestone events and deliverables, the associated schedule and interdependent deliverables:

#	Milestone Event	Deliverable	Schedule	Interdependent Deliverables
1	Technical Plan of Operations Delivery	Technical Plan of Operations	2-Jul-15	NA
2	Draft Pilot LC Delivery	Draft Pilot LC Data	14-Aug-15	1
3	Corrective Actions from Pilot Delivery	Revised Draft Pilot LC Data	28-Aug-15	2
4	Final Pilot Data Acceptance	Final Pilot LC Data	4-Sept-15	2,3
5	Bay Watershed LC - 1st Area Delivery	1st Area Bay Watershed LC	30-Nov-15	4
6	Bay Watershed LC - 2nd Area Delivery	2nd Area Bay Watershed LC	05-Feb-16	4
7	Bay Watershed LC - 3rd Area Delivery	3rd Area Bay Watershed LC	15-Apr-16	4
8	Bay Watershed LC Corrective Action	Corrected Bay Watershed LC	20-May-16	5,6,7
9	Final Bay Watershed LC Acceptance	Final Bay Watershed LC	10-Jun-16	8
10	Remainder State LC - 1st Area Delivery	1st Area Remainder State LC	22-Jul-16	9

11	Remainder State LC - 2nd Area Delivery	2nd Area Remainder State LC	02-Sep-16	9
12	Remainder State LC - 3rd Area Delivery	3rd Area Remainder State LC	14-Oct-16	9
13	Remainder State LC Corrective Action	Corrected Remainder State LC	18-Nov-16	10,11,12
14	Remainder State LC Final Acceptance	Final Remainder State LC	23-Dec-16	12,13

Table 5: Project Milestones, Deliverables and Schedule

3.2 Project Tracking

3.2.1 JIRA and Confluence

WorldView will be using Atlassian cloud software JIRA and Confluence internally to help coordinate and track project progress using agile project management techniques. WorldView has broken the state into working areas based on flight and spectral variation, which can be further subdivided into a coordinating tile grid. Each of these tile areas will be tracked for task completion. Tasks will be broken out and assigned to a particular analyst, along with comments on output and cells highlighted based on QA status. As new tasks are identified, the Technical Lead will coordinate with the Imagery Analysts to maintain consistency throughout the project. Percent complete for project tasks will be calculated on a weekly basis and reviewed against the scheduled delivery dates. This data will also be shared with the project partners for status reporting.

3.2.2 Status Meetings

Any issues with data cleanup or classification, including potential barriers to the timeline, will be discussed between WorldView and project partners during status meetings. On-site meetings will be held at WorldView headquarters where staff can share methodologies, data, questions/concerns, and any other items relating to project details and schedule tracking. Once the pilot areas have been completed and reviewed, as well as corrective actions worked out between partners, these meetings can be held on a bi-weekly basis to review project status and deliverables.

3.3 Project Status Reporting

3.3.1 Bi-Weekly Status Reports

As part of its commitment to project management, WorldView will provide bi-weekly status reports via email to all project stakeholders, covering progress on all project tasks. Reports will include:

- Approximate progress as a percentage of total project deliverables
- Tasks completed
- Expectations for the next reporting period
- Issues requiring action or feedback
- Additional comments or concerns

3.3.2 ArcGIS Online Status Maps

An ArcGIS Online Group will be created on the WorldView Organizational Account to share project status on a bi-weekly basis to correspond with the bi-weekly status report. All project stakeholders will be invited to the group. Those without ArcGIS Online accounts will be added temporarily as named users within the WorldView Organization in order to participate. This will allow all project stakeholders to access the spatial representation of project completeness.

3.3.3 Delivery Acceptance Forms

Delivery acceptance forms, delivered at each milestone delivery will also be provided via email, describing deliverables/project tasks completed.

Appendix A

Land Cover Classification Constituents

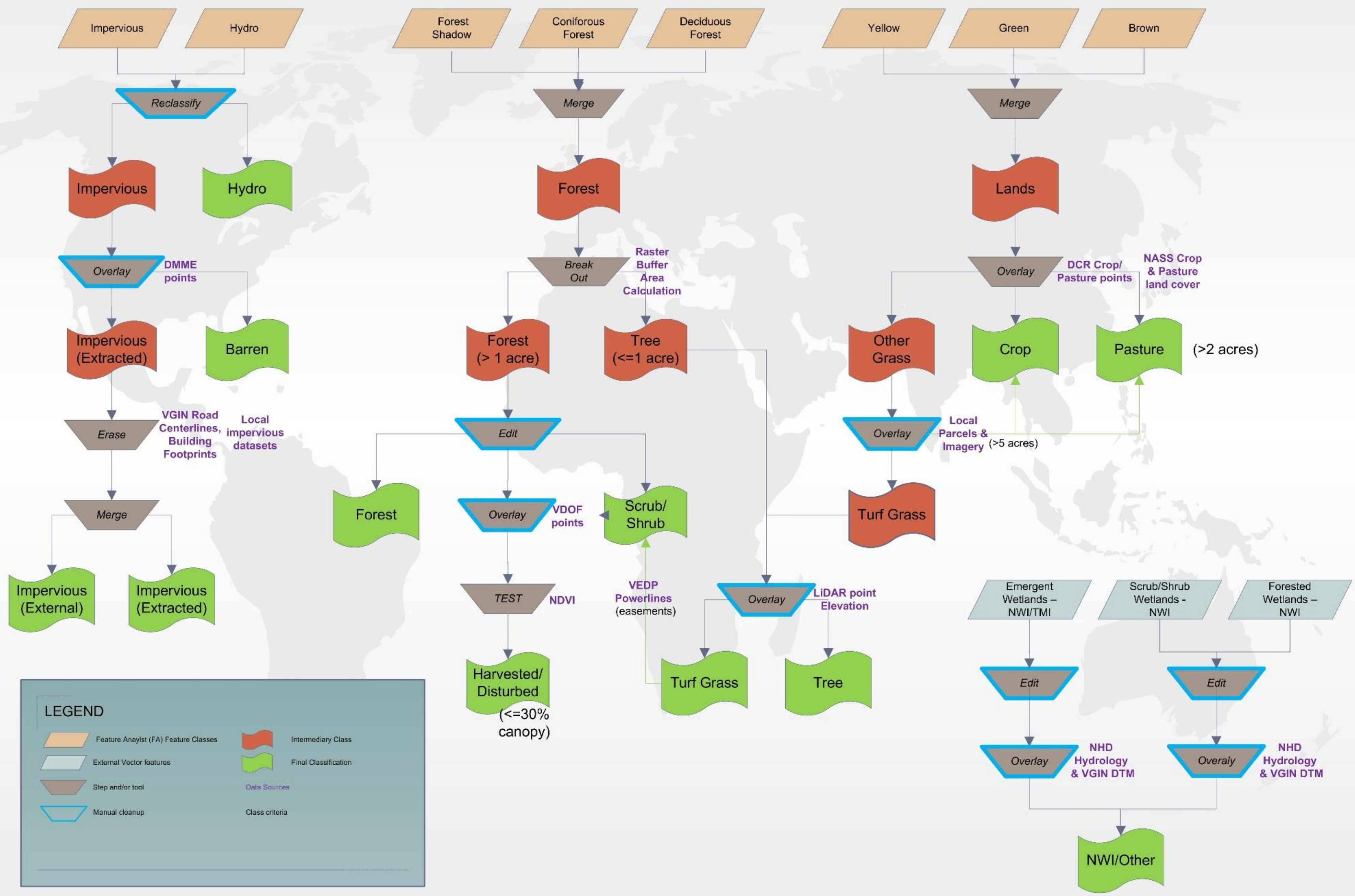
Category	Classification	Minimum Mapping Unit	Resolution	Accuracy	Data Sources	Bounding Criteria
Herbaceous	TurfGrass	Less than 2 acres with land use exceptions	1 Meter	85%	VBMP, VGIN Parcels	None
Impervious	Impervious (Extracted & External)	Match resolution	1 Meter	95%	VBMP, VGIN Roads, VGIN Buildings, VGIN Parcels, Locality Planimetrics, VGIN DTM	None
Forest	Forest	1 acre / size ratio restriction	1 Meter	95%	VBMP, VDOF	> 30% canopy cover
Forest	Tree	<= 1 acre / size ratio	1 Meter	85%	VBMP, VDOF	> 30% canopy cover
Forest	Harvested/Disturbed Forest	1 acre / size ratio restriction	1 Meter	85%	VBMP, VDOF Timber Permits	<= 30% canopy cover
Scrub/Shrub	Scrub/Shrub	1 acre / size ratio restriction	1 Meter	85%	VBMP, Elevation Data	None
Agriculture	Cropland	As defined by NRCS	1 Meter	85%	VBMP, VGIN Parcels, DCR Agriculture, DCR BMPs, NAIP, AgCensus	> 5 acre parcel size
Agriculture	Pasture	As defined by NRCS	1 Meter	85%	VBMP, VGIN Parcels, DCR Agriculture, DCR BMPs	> 5 acre parcel size
Wetlands	NWI/Other	As defined by NWI/TMI	1 Meter	85%	VBMP, NHD Hydrology, TMI, NWI wetlands, Elevation Data	None
Barren	Barren	1 acre / size ratio restriction	1 Meter	85%	VBMP, VDMME Mining Permits	None
Water	Water	Higher than the resolution	1 Meter	95%	VBMP, NHD Hydrology, VGIN DTM, Locality Planimetrics	Inside NHD hydro

Appendix B

Land Cover Technical Workflow Details

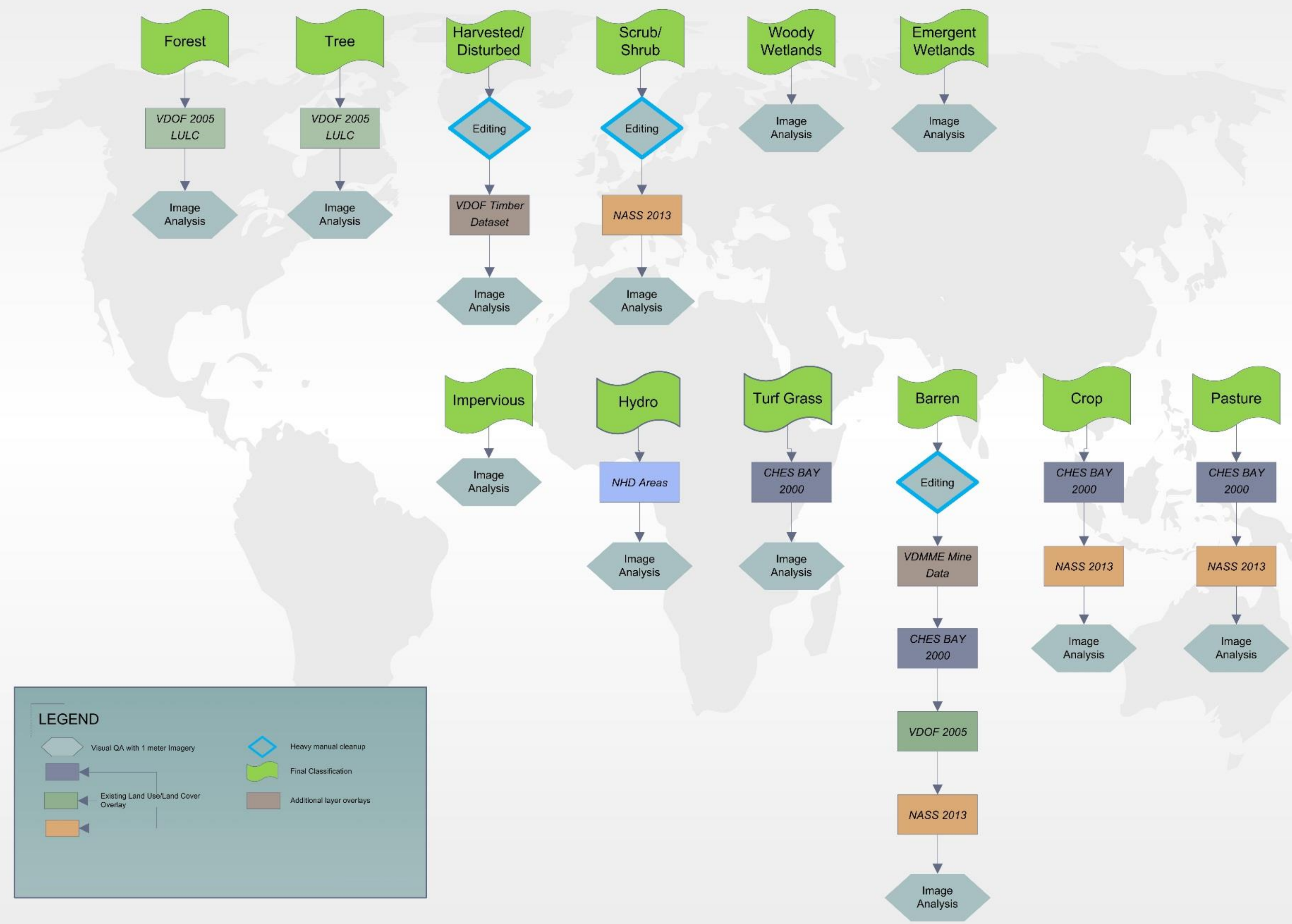
VGIN Land Use /Land Cover Workflow

Friday, April 08, 2016



VGIN Land Use /Land Cover QAQC

Friday, April 08, 2016



Statewide Land Cover - Technical Workflow

KEY:
This text refers to layers in SDE used to track progress for tiles
This text refers to network path directories for data/tools described
This text refers to batch processing step for tiles with ESRI & Feature Analyst AFE models & Parameters
This text refers to output names

I. Preliminary Tasks

1) VBMP RCL dataset
   a) Prep RCL
      i) Get the matching year for the RCL centerline data
         (1) 2013 delivery areas:
         \\nas-1.wvs\LULC\Data_Downloads\VGIN_Localities\VBMP_RCL_FGDB_Q12014.gdb\RCL
         (2) 2015 delivery areas:
         \\nas-1.wvs\LULC\Data_Downloads\VITA\VBMP_RCL_FGDB_2015Q1\VBMP_RCL_FGDB.gdb\RCL
      ii) Clip that line data to your delivery area for faster processing (can save in temp folder)
      iii) Run 'Feature to Point' geoprocessing tool to create centroid points from RCL centerlines
         (1) Input: RCL centerline clip
         (2) Output into temp folder as point layer
         (3) Check to create "inside feature"
   b) Prep Navteq
      i) Get the matching year for the Navteq data
         (1) 2013 delivery areas:
         \\misterburns\Nokia_Workspace\SourceData\Navteq\2014Q1\NavStreets\USA\StateClips\VA\Streets
         (2) 2015 delivery areas:
         \\misterburns\Nokia_Workspace\SourceData\Navteq\2014Q4\NavStreets\USA\StateClips\VA\Streets
      ii) Clip that line data to your delivery area for faster processing (can save in temp folder)
      iii) Run 'Buffer' on export of Navteq centerlines
         (1) Input: Navteq streets clip
         (2) Output into temp folder as bufferlayer
         (3) Linear Unit: 25 ft
         (4) Dissolve Type: None
         (5) The rest are default settings, OK
   c) Create final RCL fileds for buffering
      i) Run Spatial join to add Navteq attribution to RCL centroid pts
         (1) Target: RCL pts
         (2) Join: Navteq Buffer
         (3) Output into temp folder as spatial join point layer
         (4) JOIN ONE TO ONE
         (5) The rest are default settings, OK
      ii) Join RCL Spatial Join points table to RCL centerlines based on 'RCL_ID'
         (1) Keep all records

iii) Create new fiields

(1) new ‘LANES’ field, short integer

(a) Field calculator:

(i) [RCL_R1_FeatureToPoint_Spatia.TO_LANES] + [RCL_R1_FeatureToPoint_Spatia.FROM_LANES]

(2) new ‘NAV_FUNC’ field, short integer

(a) Field calculator:

(i) [RCL_R1_FeatureToPoint_Spatia.FUNC_CLASS]

iv) Remove Join

v) Field calculate new 'LANES' field based on the following selections

(1) Select by Attributes:

(a) (NAV_FUNC = 5 OR NAV_FUNC=1) & VDOT_FUNC= ' '

(b) Field Calculator:

(i) 1

(2) Select by Attributes:

(a) (NAV_FUNC = 5 OR NAV_FUNC=1) & VDOT_FUNC <> ' '

(b) Field Calculator:

(i) 2

vi) Create final ‘BUFFER’ field, short integer

(1) Field calculator:

(a) [LANES] * 2

(based on 1 lane being 12 ft, which is 4 meters, and the buffer being half the meters)

d) Run 'Buffer' tool on RCL centerlines with new Buffer field

i) Input: RCL centerlines

ii) Output: \\Artie-pc\VGIN\Processing\RCL_BUFFER_*Remainder1*.shp (or which ever area)

iii) Field: BUFFER

iv) Dissolve: ALL

2) <u>Hydro</u>

a) NWI dataset

i) Run a definition query to only include the following classes:

(1) Freshwater Pond

(2) Lake

(3) Riverine

(4) Estuarine and Marine Deepwater

b) NHD dataset

i) Run a definition query to only include the following codes:

(1) NHD Waterbody

(a) LakePond – 390

(b) Reservoir – 436

(2) NHD Area

(a) StreamRiver – 460

c) DTM

i) Use LiDAR data to extract water features

d) Local Hydro Features

i) Determine Subtypes and exclude those that do not qualify (swamp, etc)
ii)
e) Only include those features greater than 1 acre
f) Check hydro polygons (both Areas & Waterbodies) for accuracy
i) Mark “yes” under new ‘BAD’ field if features don’t follow aerials
(1) Underrepresentation of actual waterbodies OK
(2) If features extend into wetland ground OK
(3) If features overlap other classification (forest, ag, etc) then BAD
ii) When all areas completed, export only those features where BAD=”NULL”

3) Wetlands – NWI, TMI, and NHD datasets
a) Woody Wetland
i) NWI
(1) Run a definition query to only include the following classes:
(a) Freshwater Forested/Shrub Wetland
(i) FO
(ii) FO/EM
(iii) FO/SS
(iv) SS
(v) SS/EM
(b) Estuarine & Marine Wetland
(i) FO
(ii) FO/EM
(iii) FO/SS
(iv) SS
(2) Check for accuracy, only using those features that follow aerials
b) Emergent Wetland
i) NWI
(1) Run a definition query to only include the following classes:
(a) Freshwater Emergent Wetland
(i) EM
(ii) FO/EM
(iii) SS/EM
(b) Estuarine & Marine Wetland
(i) SS/EM
(ii) EM
(2) Check for accuracy, only using those features that follow aerials
ii) TMI
(1) All features emergent
(2) Check for accuracy, only using those features that follow aerials

II. Local Accuracy Checks

1) Produce Random Points
As local data comes in, will need to be merged, dissolved, and models ran to check accuracy
a) Heads up visual check for overall accuracy and file format initially (must be .shp or fgdb)
b) All good impervious datasets pushed to county folder on server
\\nas-1.wvs\lulc\QC\Received_Data\Local\Impervious

        i) Buildings
        ii) Edge of pavement
        iii) Concrete pads, parking lots, etc
    c) All remaining datasets pushed to county folder Non-Imperv
       \\nas-1.wvs\lulc\QC\Received_Data\Local\Non_Impervious
    d) Script to develop accuracy pts on impervious datasets using "Create Random Points" geo-processing tool
        i) As soon as data is added to local impervious county folder, QC Local Data script will be ran
           \\nas-1.wvs\lulc\Scripts\QC\Local_Data.pyt\QC_Local_Data
           (1) checks for new data added
           (2) All new shapefiles/feature classes will be merged and dissolved
           (3) Develops random set of 50 pt features (50 ft min. distance btwn pts) based on dissolved dataset, appends to Random_Points feature class with existing domains
           (4) Updates Local_Status table in same gdb to say percent accuracy, if passing, and what features contributed
               Mark Tiles field 'Local_pts_ready' "Yes"

2) <u>Accuracy check performed</u>
    a) Technician will open accuracy 'QC_Checks.gdb' and look for NULL attributed pt features
       \\nas-1.wvs\lulc\QC\Received_Data\Local\QC_Checks.gdb
    b) Technician will compare points to VBMP imagery and mark fields appropriately
        i) YES/NO matches aerials
        ii) Correct Classification
            Mark Tiles field 'QC_Local_complete' "Yes"

3) <u>Add percent accuracy to county list</u>
    a) Technician will run QC Local Data script once again to pull results from accuracy check
       \\nas-1.wvs\lulc\Scripts\QC\Local_Data.pyt\QC_Local_Data

4) <u>Add *passed* features to local tile folder</u>
    a) Technician will run Tile Local Data script to cut impervious county data and append into tiled folder (script used in later steps to append buildings/VBMP/etc)
       \\nas-1.wvs\lulc\Scripts\QC\Local_Data.pyt\Tile_Local_Data
        i) Intersects county impervious data with Index_Dissolve for state to get tiled pieces
        ii) Spatially joins with VA County census data to get county name attribution
        iii) Appends into final tiled feature class that will be used to as a mask during feature extraction, as well as to merge data back in after extraction of a tile
            Mark Tiles field 'Local_passed':
                1. "N/A" – If there was no data available to use (0)
                2. "Yes" – If data passed accuracy (1)
                3. "No" – If data did not pass accuracy (2)

<u>III. Extraction Process – FA (Feature Analyst) Software</u>

1. <u>Create Training Samples</u>

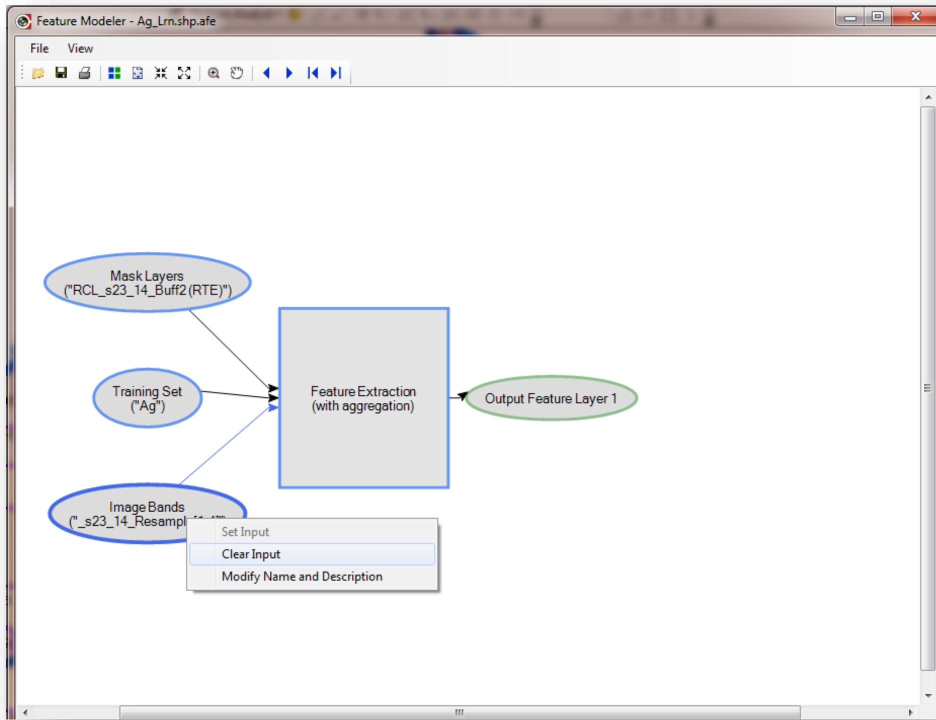
   Will be completed for one tile within each specified Mosaic Area developed (will batch process to other tiles within)

   - Barren*

- Harvested*
- Ag*
- Hydro
- Impervious
- Deciduous Forest
- Coniferous Forest
- Forest Shadow
- Yellow
- Brown
- Green

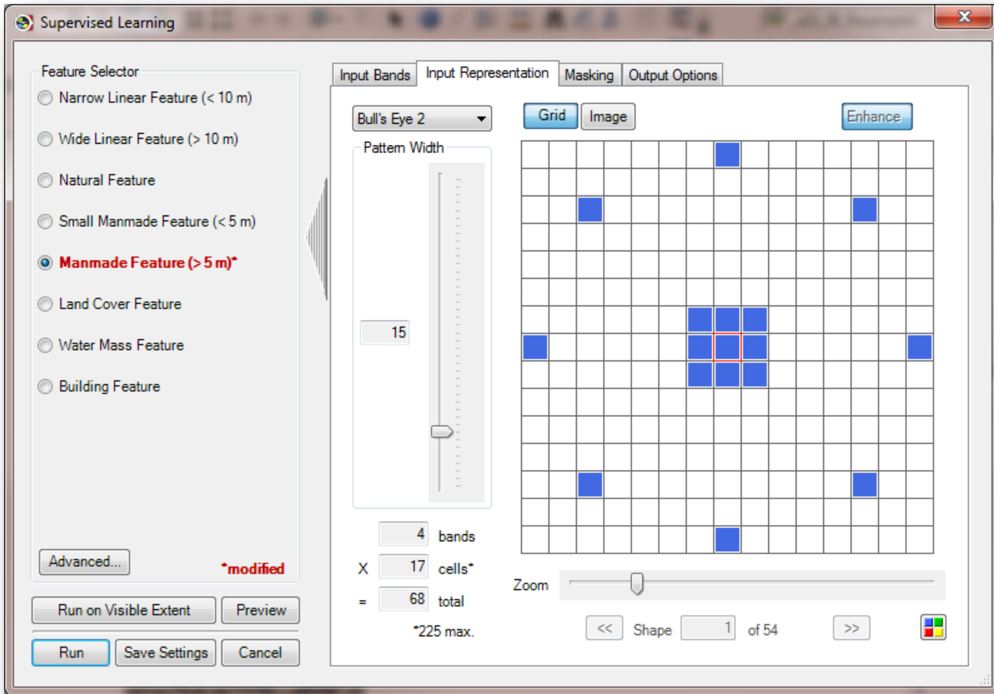
*some classes there may be no samples, so you will need to exclude these from learning, or the learning pass will fail

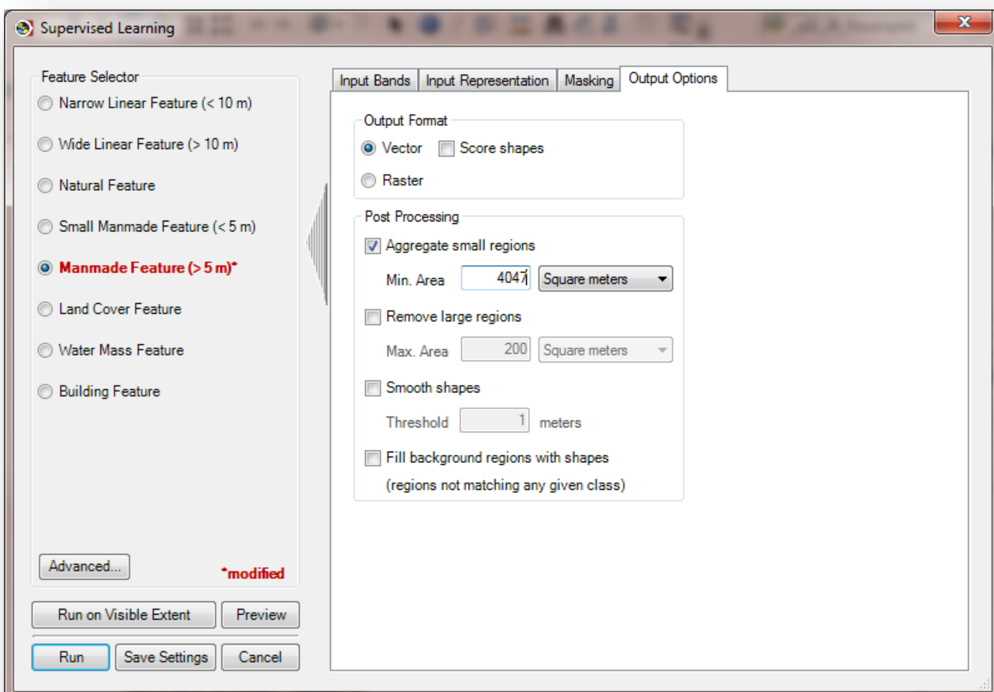
2. Run Learning Pass, then cleanup, on single classes
(can skip a class if there are no samples in that area)
Only needs to be done for 1 tile in each mosaic area.. If Batch Processing, follow BLUE text and skip to Manual Cleanup
    a. Ag
    \\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\Ag_Lrn.shp.afe
        - Bring RCL buffer & Imagery for tile you are working on
        - Open Feature Modeler from FA Toolbar, open Ag_Lrn.afe for that mosaic area
        - Right-click on each step to Set Inputs:
            - Image Bands
            - Mask Layers (RCL Buffer – Region to Exclude)
        - Set Output (similar to above directory, but for tile you are working on)
        - RUN model



*This image represents the Feature Modeler window and settings when opening an existing

i. Bring in Imagery for the tile you are working on
   \\Artie-pc\vgin\Imagery\STATE_PLANE
ii. Bring in RCL Buffer
   \\Artie-pc\vgin\Data_Created_WVS\RCL_Bay1_BUFFER.shp
iii. Supervised Learning
   1. Manmade Feature, Pattern Width: 15
   2. Aggregation = 4,047 sq m
   3. Mask layers:
      a. RCL buffer
   4. Output: \\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\ Ag_Lrn
      Mark Tiles field 'Ag_Lrn' "Yes"





*These images represent Ag settings for Supervised Learning feature extraction

b. Barren
[\\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\Barren_Lrn.shp.afe](\\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\Barren_Lrn.shp.afe)

- Bring in RCL buffer, Ag_Lrn_FINAL, & Imagery for tile you are working on

- Open Feature Modeler from FA Toolbar, open Barren_Lrn.afe for that mosaic area
- Set Inputs:
  - Image Bands
  - Mask Layers (RCL Buffer, Ag_Lrn_cleaned – Regions to Exclude)
- Set Output (similar to above directory, but for tile you are working on)
- RUN model

i. Bring in RCL Buffer
\\Artie-pc\vgin\Data_Created_WVS\RCL_Bay1_BUFFER.shp

ii. Bring in Ag_Lrn_FINAL shapefile

iii. Supervised Learning
1. Manmade Feature
2. Aggregation = 15,000 sq m
3. Mask layers:
   a. RCL buffer
4. Output: \\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\ Barren_Lrn
   Mark Tiles field 'Barren_Lrn' "Yes"

c. Harvested
MUST HAVE AG CLEANUP COMPLETE
\\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\Harv_Lrn.shp.afe

- Bring in RCL buffer, Ag_Lrn_FINAL, Barren_Lrn_FINAL, & Imagery for tile you are working on
- Open Feature Modeler from FA Toolbar, open Harv_Lrn.afe for that mosaic area
- Set Inputs:
  - Image Bands
  - Mask Layers (RCL Buffer, Ag_Lrn_FINAL, Barren_Lrn_FINAL – Regions to Exclude)
- Set Output (similar to above directory, but for tile you are working on)
- RUN model

i. Bring in RCL Buffer
\\Artie-pc\vgin\Data_Created_WVS\RCL_Bay1_BUFFER.shp

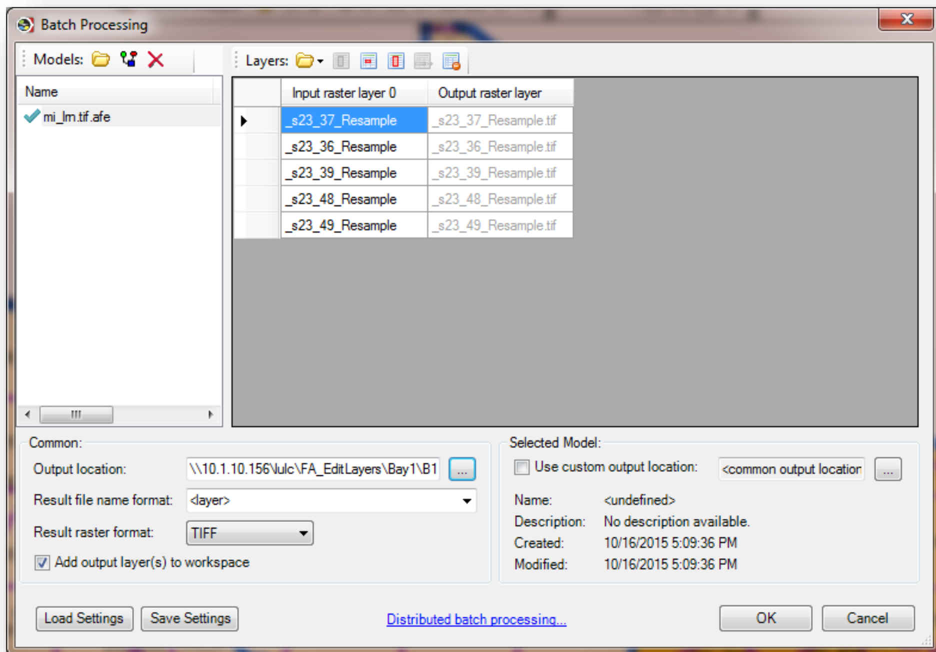
ii. Bring in Ag_Lrn_FINAL shapefile

iii. Supervised Learning
1. Manmade Feature
2. Aggregation = 7,000 sq m
3. Mask layers:
   a. RCL buffer
   b. Ag_Lrn_FINAL
4. Ouput: \\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\ Harv_Lrn
   Mark Tiles field 'Harv_Lrn' "Yes"

3. Create Multi-class Input layer from all remaining classes
(can be Batch Processed per mosaic area)
Only needs to be done for 1 tile in each mosaic area.. If Batch Processing, follow BLUE text and skip to Split out classes

\\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\MI_Lrn.tif.afe

- Open Batch Processing from FA Toolbar, open MI_Lrn.tif.afe model for that mosaic area
- Set Inputs layers:
  - Image Bands
- Set Output (similar to above directory, but for the entire mosaic area) as TIFF
- RUN model
- When complete, make copies as 'MI_Lrn_cmb.tif' in tile folders here: \\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\



*This image represents the Batch Processing window when opening an existing model and adding imagery inputs for that mosaic area

a. Highlight the following layers and create Multi-Input layer (must be added to map in correct order)
   - Brown
   - Conif
   - Decid
   - DecidShadow
   - Green
   - Hydro
   - Imperv
   - Yellow
b. Run Learning Pass on Multi-Input layer
   i. Supervised Learning
      1. Land Cover Feature (Resample needs to be changed back to "1")

2. Aggregation = 50 sq m
3. No Masking
4. Output: Raster - \\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\MI_Lrn.tif

ii. When complete, review for accuracy

1. If classifications reflect the VMP imagery well, make copy as 'MI_Lrn_cmb.tif' in:
\\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38
Mark Tiles field 'MI_Lrn_passed' "Yes"
2. If it appears that a class could be better refined, new training sets will need to be created in that tile and a new combined supervised classification ran on that tile
Mark Tiles field 'MI_Lrn_passed' "No"
When a new output passes, mark Tiles field 'MI_Lrn_fixed' "Yes"

IV. Forest Extraction Process – LA (LIDAR Analyst) Software

1. Extract Forests from LIDAR

a. Create Tile Index

i. Select tiles within Census Urbanized Areas

ii. If different LIDAR extracts have different projections, preserve projection for tiles corresponding with LIDAR

1. FEMA, ARRA, ESVA, NRCS, USGS, NCR – VA State Plane US foot
2. Sandy CVA – UTM Zone 18N meters

b. Decompress LIDAR .zlaz and .laz to .las

i. zLAZ
\\nas-1.wvs\LULC\LIDAR\Tools\ezlas

1. Run ezlas application, select folder of .zlaz files, and set to decompress:

ii. laz
\\nas-1.wvs\LULC\LIDAR\Tools\lastools\ArcGIS_toolbox\LAStools Production.tbx\laszipPro

1. Run laszipPro with input file format as .laz and output as .las:

c. Extract First and Last Returns
\\nas-1.wvs\LULC\LIDAR\LA Models\Models\Forest\FR_LR_1m_usfoot.afe
\\nas-1.wvs\LULC\LIDAR\LA Models\Models\Forest\FR_LR_1m_meters.afe

- Open Batch Processing from LA Toolbar and open model that corresponds with units of LAS files (i.e. meter or US foot). The units of a LAS file can be determined via View LAS Header in LA Toolbar.
- Add LAS files
- Set output location

d. Combine First and Last Returns
To extract a seamless forest dataset, the first and last returns must each be combined into a single raster dataset.
Due to tool memory limitations, the tool can only handle a maximum of 75 LIDAR files at once. Therefore the LIDAR tiles must be broken into compact units of 50-75 tiles, and each group will have one single first and last return image created via this step.
\\nas-1.wvs\LULC\Scripts\Lidar\Setup.pyt\CombineReturns

i. Run Combine_Returns toolbox

1. Input directory containing extracted first and last returns

2. Distributes first and last returns into separate folders
3. Creates a single raster dataset for each return, FR.img (First Return) and LR.img (Last return)

e. Extract Bare Earth
\\nas-1.wvs\LULC\LIDAR\LA Models\Models\Forest\Extract_Bare_Earth_ow.afe
- Open Feature Modeler from LA Toolbar and add model.
- Add FR.img and LR.img to map document
- Set first return and last return inputs of model to corresponding raster datasets
- Set output of Bare Earth i.e. BE.img
- Run model. The process may take 12 - 15 hours.

f. Extract Forest
Both forest and shrub models are needed to extract both forest areas and smaller trees and shrubs in yards that may be between 1-4 meters in height.
\\nas-1.wvs\LULC\LIDAR\LA Models\Models\Forest\Extract_Shrub.afe
\\nas-1.wvs\LULC\LIDAR\LA Models\Models\Forest\Extract_Forest.afe
- Open Feature Modeler from LA Toolbar and add Shrub model.
- Input Bare Earth extraction and run model.
- Repeat for Forest.

2. Process Forest Extractions

a. Cleanup Forests
Combine forest extractions into single feature class and perform automated cleanup tasks
\\nas-1.wvs\LULC\Scripts\Lidar\Forests.pyt_2_CombineFeatures
i. Run script on geodatabase with extracted forest features
1. Merge into single feature class
2. Remove fields added from LIDAR Analyst
3. Dissolve into single part features
4. Eliminate gaps < 0.3 acres in size

b. Create Limits of Imagery
The LIDAR imagery does not always cover the extent of the tiles. The limits of imagery is needed to identify the true coverage of where forests were extracted from LIDAR.
i. Create directory with containing each FR.img for all LIDAR processing groups.
\\nas-1.wvs\LULC\Scripts\Lidar\Forests.pyt_2_CreateImageLimits
ii. Run script to extract limits from all FR.img rasters in directory via the following process:
1. Convert raster values to 0 by a conditional
2. Export raster to polygon

c. Create Extent of Forest Features
Since the LIDAR data is extracted at a resolution of 1m, the forest features will not meet the extents the limits of the imagery. The LIDAR tiles and limits of imagery are used to get the extent of forest features.
\\nas-1.wvs\LULC\Scripts\Lidar\Forests.pyt_3_ExtractForestExtents
i. Run script to create extent of forest features via the following process:
1. Intersect forest features and tiles and dissolve on unique Tile ID

2. For each tile of forest features, run geoprocessing tool Minimum Bounding geometry
3. Merge all outputs of minimum bounds and dissolve
4. Clip minimum bounds to limits of imagery and export feature class
5. Output: [Name of LIDAR group]_extents

d. Consolidate Outputs
After all forest features and extents of forest are created, merge all outputs into single feature class to integrated into Land Cover after processing
\\nas-1.wvs\LULC\Scripts\Lidar\Forests.pyt_4_ConsolidateFinalFeatures
   i. Extracted Forest Features: Forests_Final
   ii. Extracted Extents: Extents_Final

V. Cleanup Ag, Barren, Harvested, and Scrub/Shrub

1. Ag
   a. Cleanup
      1. Export Ag_Lrn from Artie-PC to Ag_Lrn_FINAL on nas-1
         \\Artie-pc\vgin\Processing\Bay1\B1_2013_South_1\s23_38\Ag_Lrn.shp
         \\nas-1.wvs\LULC\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\Ag_Lrn_FINAL.shp
      2. Start editing Ag_Lrn_FINAL
         a. Remove any misclassed Harvested, Turf, Easements from output
         b. Fill in (delete vertices) holes in Ag fields where they shouldn't be
         c. Delete extraneous pieces of Ag fields where falls into other classes
         d. Digitize any missed Ag features (scale 1:1500)
            See MaintenanceGuide on OneDrive
   b. Reclassification
      i. Use NAIP imagery to review Ag fields when determination is indecipherable from the VBMP.
         \\nas-1.wvs\lulc\Data_Downloads\NAIP_Virginia_2014_1m.lyr
      ii. Reclassification should occur in the following order as you approach each Ag field
         1. Cropland
            a. Blatant rows (careful to distinguish between mowing)
            b. Planted point features (will be planted generally in a pattern across entire field)
            c. Look for signs of crop machinery in imagery (waterwheel/fertilizers/etc)
         2. Pasture
            a. Cows visible in imagery
            b. Blatant cow/animal tracks in a more fluid pattern
         3. Look at NAIP next to decide on those fields that are uncertain
            a. Uniform green color with no signs of patchy grass
            b. Very bright/limy or very dark green color, brown color, or white/beige color fields
            c. Blatant rows
         4. For those that are still questionable:
            a. look at shape

i. Where fields do not have angular features and/or tend to flow into the forest at various edge points, these are most likely pasture

b. Refer to prior years of imagery (GIS Server: http://gismaps.vita.virginia.gov/arcgis/services - VBMP years)

i. May help where features are not visible, but be aware that land use can have changed

c. Look at NASS_2013 Pasture (36/37/176?) and Crop(others) or Ches Bay NLCD_01 Pasture/Cultivated Crops

iii. Add DCR BMP Pts to mxd, zoom to each and use as guide to edit/reassign to each class
\\nas-1.wvs\lulc\Data_Downloads\DCR\BMP4LU.shp

a. Check CompletionDate & PostLU, if date is before that of imagery then look at PreLU for remaining features from later years than imagery (can symbolize in map)

i. If LU value says "Pasture/Hay" calc Class 81

ii. If LU value says "Row Crop" calc Class 82

iii. If LU value says "AgLand" use best judgement from imagery, but can be mainly a resource for missed features

2. If there are TurfGrass polygons (less than 1 acre) that overlap the points, add them in and reclass accordingly

iv. Add Bill's remote sensing pts to mxd, zoom to each and reassign as Pasture
\\nas-1.wvs\lulc\Data_Downloads\Other\LL_all_092415.shp

1. Similar to previous step, but all points are Class 81
Mark Tiles field 'Ag_Lrn_cleaned' "Yes"
PHASE 1 COMPLETE

2. Barren/Harvested/Scrub
Use the Progress_Index to run through the tile, editing all 3 features at once:

a. Scrub/Shrub Digitizing

i. Create an empty shapefile Scrub_Lrn_FINAL on Nas & digitize features in
\\nas-1.wvs\LULC\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\Scrub_Lrn_FINAL.shp

1. Name: Scrub_Lrn_FINAL
2. Polygon
3. Coordinate System: NAD 1983 HARN StatePlane Virginia *South/North* FIPS

ii. Add Powerlines feature class to mxd
\\nas-1.wvs\lulc\Data_Downloads\VEDP\shapefiles\Powerlines.shp

iii. Start editing Scrub_FINAL

1. Run through imagery and digitize any features that appear as easements along the power lines
See MaintenanceGuide on OneDrive

b. Barren Cleanup/Digitizing

i. Create empty shapefile Barren_Lrn_FINAL on Nas & digitize features in
\\nas-1.wvs\LULC\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\Barren_Lrn_FINAL.shp

ii. Start editing Barren_Lrn_FINAL

a. Remove anything transitional, only leaving bare rock/sand/clay
b. Remove any roads connecting pieces, or other impervious features

c. Add missed bare features such as beaches, mineral piles, & major construction sites
d. Add DMME mining pts to mxd, zoom to each and use as guide to edit/reassign to this class
\\nas-1.wvs\lulc\Data_Down-loads\DMME\April15_2015.gdb\April15_2015.gdb\DMLR_Permits\Released_Permit_Loc
See MaintenanceGuide on OneDrive

c. Harvested Cleanup/Digitizing
   i. Create empty shapefile Harv_Lrn_FINAL on Nas & digitize features in \\nas-1.wvs\LULC\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\Harv_Lrn_FINAL.shp
   ii. Start editing Harv_Lrn_FINAL
      a. Add VDOF Harvest points to find general areas to refer to
         i. In the end we will only keep areas of Harvested that are not regrown beyond 30%. If you are unsure and looks maybe 50/50, keep for now (will run NDVI test next)
      b. Use Harv_Lrn from Artie-PC to copy/paste features into Harv_Lrn_FINAL as available
      \\Artie-pc\vgin\Processing\Bay1_New\B1_2013_South_1\s23_38\Harv_Lrn.shp
      c. Add/digitize missed areas
      See MaintenanceGuide on OneDrive

Mark Tiles field 'BASH_cleaned' "Yes"
PHASE 2 COMPLETE

VI. Run NDVI/Union and QA Ag, Harvested, Barren, Scrub/Shrub

1. Run mean NDVI & Union script
   a. Run the Combine BASH script
   \\nas-1.wvs\lulc\Scripts\Processing\BASH.pyt\Combine_BASH
      i. Script will create a second shapefile with mean NDVI values for each polygon
         1. Runs NDVI function
         2. Runs Zonal Statistics Table tool (Spatial Analyst)
         3. All features from the Harv_Lrn_FINAL layer that exceed a value of 115 will be removed
      ii. Script will also create a union of features
         1. Dissolves each feature class and removes features < 1 acre in size
         2. Runs a union of Ag, Harvested, Barren, Scrub/Shrub
         \\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\bash_combined.shp
            (a) Output Feature Class: bash_combined.shp
            (b) Adds a field 'Overlap'
               (i) If features overlap, field ClassID is calculated to 0 and the field 'Overlap' identifies the overlapping features, i.e. pasture/crop or harvested/barren/scrub

(ii) If features do not overlap, ClassID remains unchanged and 'Overlap' is left blank

Mark Tiles field 'NDVI_ready' "Yes"

2. QC BASH tile layers
   a. Bring in bash_combined.shp for chosen tile (Barren, Ag, Scrub, & Harvested) into mxd
      \\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\bash_combined.shp
      i. Turn on imagery for that tile and scan through to look for errors
         1. Missed features
         2. Misclassification
            (a) Harv in as Barren
            (b) Pasture as Crop
            (c) etc
         3. Features digitized that should not be included
            (a) turf areas added as Harv
            (b) etc
         4. Missed features (but not Harv if it was removed from the original)
            (a) You can check the Harv_Lrn_FINAL_NDVI layer in the same folder to see if feature just got missed
      ii. Review overlap
         1. Reclassify all overlapping features (CLASS_ID= 0) depending on which feature listed in the 'overlap' field is correct
            (a) Pasture to '81'
            (b) etc
   b. Make any other necessary edits
      See MaintenanceGuide on OneDrive

Mark Tiles field 'QC_BASH_complete' "Yes"

PHASE 3 COMPLETE

VII. Automated Extraction Cleanup and External Dataset Integration

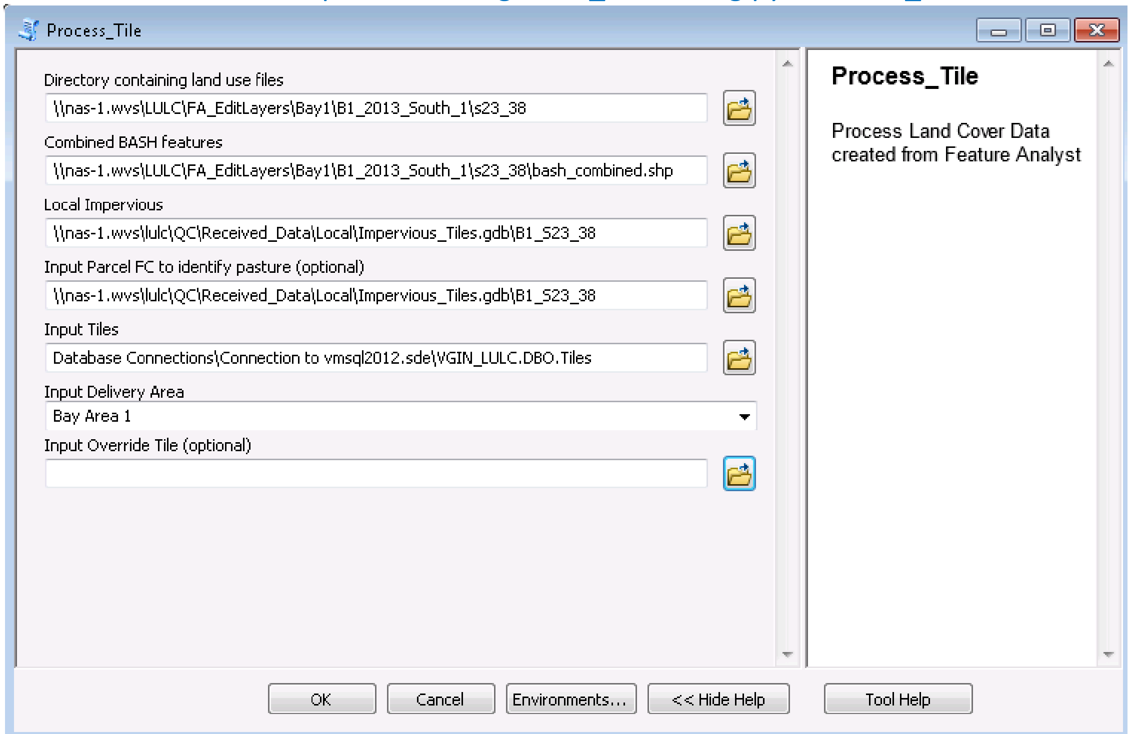
1. Prep Local data for next step
      i. Check Local_Ready table for 'Complete' = "Yes"
         \\nas-1.wvs\QC\Received_Data\Local\QC_Checks.gdb\Local_Ready
         1. If "Yes," but there are counties listed under 'No_Data', check spreadsheet if we are just waiting on data still, otherwise we can accept that there's no more data needed
            S:\VGIN\LandUse\project_docs\design\data\LocalityDataRequests
         2. If 'Complete' = "No," check Local_Status to see if accuracy check just needs to be completed
            a. Complete accuracy check (See Part II, 2a)

PHASE 4 COMPLETE

Check if 'MI_Lrn_passed' is "yes", if so PHASE 5 COMPLETE

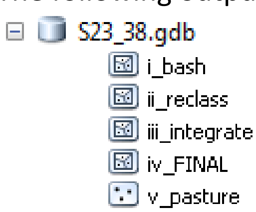
2. Run python toolbox or python script for each tile
   a. Multiple outputs will be exported into a geodatabase as the following stages of the script are completed.

\\nas-1.wvs\lulc\Scripts\Processing\LULC_Processing.pyt\Process_Tile



*This image represents the inputs to run processing on a selected tile

The following outputs are created:



\\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38

3. Integrate Forest LIDAR
   If tile intersects LIDAR forest extraction, integrate LIDAR forests into iv_FINAL
   \\nas-1.wvs\LULC\Scripts\Lidar\Forests.pyt_5_IntegrateForests
   a. Run script with iv_FINAL
      i) Clip LIDAR Forest to tile
      ii) Clip IV_Final to extents of LIDAR Forests
      iii) Select Turf and Forests from iv_Final
         1. Erase Forests selection by LIDAR forests
         2. If Forests completely enclosed by LIDAR forests, add to LIDAR forests
      iv) Calculate Forests selection to turf
      v) Clip LIDAR Forest to turf
      vi) Integrate LIDAR Forest into turf and iv_FINAL via a conditional
      vii) Output Feature Class: iv_FINAL_Lidar

Here is a summary of the automated steps:

1) Create geodatabase

a) Output Geodatabase named by tile
b) Add classifications domain to geodatabase

2) <u>Add Ag, Harvested, Barren, Scrub/Shrub, Wetlands to FA Extraction</u>
   a) Reclassify FA Extraction
      i) Calculate classification according to final class IDs
         (a) Select Barren and recalculate
            (i) Class 1, 5, 8 → Class 71
         (b) Select Forest and recalculate
            (i) Class 2, 3, 4 → Class 71
         (c) Select Hydro and recalculate
            (i) Class 6 → Class 11
         (d) Select Impervious and recalculate
            (i) Class 7 → Class 21
   b) Combine FA extraction and external datasets
      i) Convert external datasets to raster
      ii) Run a conditional of FA Extraction and external datasets
      iii) Export conditional raster to polygon
   c) Clip combined feature class to boundary of tile
   d) Output Feature Class: i_bash

3) <u>Extraction Cleanup – ESRI Geoprocessing Tools</u>
   1) Aggregate Features
      i) Remove Noise of small Ag, Turf & Hydro features within Forest
      ii) Select those class feature whose areas is < 3000 sq m
         (1) Classes 11, 71, 81, 82
         (2) (will have to create an area field and calculate first)
      iii) Select rom selection those that intersect Forest
         (1) Class 41
      iv) Remove from selection any of those within 25 ft of Impervious
         (1) Class 21
      v) Reclassify Selection into Forest Class
         (1) Class 41
   2) Water Cleanup
      i) Remove small Hydro features
         (1) Select Hydro and recalculate to Impervious
            (a) Class 11 → Class 21
         (2) Select Hydro and recalculate to Trees
            (a) Class 11 → Class 41
         (3) Select Hydro and recalculate to Ag
            (a) Class 11 → Class 82
         (4) Select Hydro and recalculate to TurfGrass
            (a) Class 11 → Class 71
      ii) Filter Hydro features
         (1) Select and eliminate features < 0.1 acres enclosed by hydro
            (a) Classes 21, 41, 71 → Class 11
   3) Barren Cleanup
      a) Filter Barren features

(1) Select and eliminate features < 0.1 acres enclosed by Barren
(a) Classes 21, 41, 71 → Class 11
4) Shadow Cleanup
a) Reclassify building shadows extracted as Tree
(1) Select Impervious features whose area is < 400 sq m
(2) Select Tree features whose area is < 200 sq m
(3) Reclassify those Tree features that intersect those Impervious Features
(a) Class 41 → Class 71
5) Output Feature Class: ii_reclass

4) Add External Impervious Features
a) Impervious: Local Tile with Local Impervious, RCL Buffer, & VA Buildings
\\nas-1.wvs\lulc\QC\Received_Data\Local\Impervious_Tiles.gdb
\\nas-1.wvs\lulc\Data_Created_WVS\Buildings\Buildings_ByTile.gdb
\\nas-1.wvs\lulc\Data_Created_WVS\RCL\RCL_ByTile.gdb
i) Merge local impervious data, RCL Buffer, and VA Buildings
ii) Clip merged impervious data to tile
b) Combine impervious data with ii_reclass in raster
i) Convert ii_reclass and impervious data to raster
ii) Run a conditional to integrate impervious data into ii_reclass
iii) Convert back to vector with Raster To Polygon
iv) Repair geometry and dice features exceeding 10,0000 vertices
c) Output Feature Class: iii_integrate

5) Extraction Post-Processing
a) Turf/Grass
i) Select Turf/Grass adjacent to ag fields and Forest/Tree that is not adjacent to impervious and < 0.75 acres
(1) Class 71 → Class 82
ii) Select Turf/Grass adjacent to Forest/Tree and Emergent Wetlands and not adjacent to any other classes
(1) Class 71 → Class 41
b) Eliminate Features
i) Reclassify largest neighbor on a selection of ClassID 11 < 1 acre, all classes < 0.01 acres, or impervious < 0.001 acres
(1) Run polygon neighbors analysis to find largest shared neighbor
(2) Update selection with Class ID of neighbor
ii) Output Feature Class: iv_FINAL

6) Extraction of TurfGrass/Pasture
a) Run Identity on land cover tile using Parcels > 3 acres
b) Add field 'Acres' and calculate for all features with ClassID = 71
c) Select features where FID_For <> -1, ClassID = 71, & Acres > 2
d) Run Feature to Point geoprocessing tool to extract pts for review
e) Output Feature Class: v_pasture
Mark Tiles field 'Tile_Processed' "Yes"
PHASE 6 COMPLETE

VIII. QC Tile Tasks (per tile)

The following 2 tasks will be completed in conjunction with one another:

1. Full Tile run through - make any necessary Adjustments
    a. Bring in iv_FINAL for the tile you are working on
    \\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\S23_38.gdb\iv_FINAL
    b. Bring in VBMP imagery service year for the area you are working in
    c. Start editing
        i) Heads up visual check of iv_FINAL classifications for overall accuracy
            1. May have to cut existing features
            2. Update ClassID with correct classifications
                a. Turf that should be Barren (beaches) or just part of Forest (due to leaf-off imagery)
                b. Impervious that is really just wet Cropland or really dark Hydro
                c. Pasture or Cropland that should be the other
                d. Etc
            3. Can use NASS 2013 classifications as reference for areas in question
        ii) Look for additional Scrub/Shrub
        Areas that are classified as Turf, Harvested, or Forest that obviously resemble scrub/shrub and do not fit well into the former
            1. Possibly was once Ag, but now unmanaged spotty regrowth
            2. Areas around wetlands that have shrubby growth
            3. Easements (under powerlines for example)
        iii) Look for Fish Hatcheries
            1. Use point features to locate fish hatcheries; calculate as Hydro where any tanks/pools are
            \\nas-1.wvs\LULC\Data_Downloads\Other\Fish_Hatcheries.shp
        iv) Reclassify railroads
            1. Classify as impervious, using layer package as reference; many will exist as impervious or hydro in v_FINAL
            \\nas-1.wvs\LULC\Data_Downloads\Other\Existing_Rail_in_Virginia.lpk
        v) ACCURACY ITEMS TO FOCUS ON
            1. Incorrect Forest/Tree that appears in Crop fields
                a. Should be caught during Ag_cleanup OR QC_BASH, but still getting missed
                b. Look for areas within Crop fields that are showing as trees due to planting patterns or dark row crops and reclassify back to Crop
            2. Incorrect Turf that appears in Forest
                a. Should see a lot of this during Tile QC
                b. Look for areas that extract as Turf due to leaf-off trees in the Forest and reclassify all back to Forest
            3. Incorrect slivers of Turf that appear around back sides of Crop & Pasture
                a. Will clean up during Tile QC; hard to see sometimes
                b. Look for Turf by running definition query at the end, or symbolizing with a contrasting color, to identify the slivers around Ag fields, then reclassify back to either Crop or Pasture
2. Reclass Turf to Pasture
    a. Add Pasture points for that tile to mxd

\\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\S23_38.gdb\v_pasture

i) Run through each feature in the attribute table of the Point feature class
   1. These will take you to Turf features in iv_FINAL that are within Parcels >= 3 acres, where the features are also greater than 2 acres
   2. Look at the feature against the imagery and see if the feature could belong to the Pasture classification instead (basically missed the first time around)
      a. If not, move to the next
         (i) Signs would be development, recreational areas (stadiums, parks, etc), air-ports, etc
      b. If so, select the feature in iv_FINAL and change the ClassID from 71 to 81
         See MaintenanceGuide on OneDrive

      Mark Tiles field 'QC_Tile_Complete' "Yes"

      PHASE 7 COMPLETE

<u>IX. Final QC Tasks (per tile)</u>

1. <u>Accuracy Check</u>

   After post-extraction & final run-through, models will be ran to check accuracy

   a. Run script to develop accuracy pts on completed tiles using "Create Random Points" geo-processing tool

      \\nas-1.wvs\lulc\Scripts\QC\LULC_Accuracy.pyt\QC_Final_Tiles
      i. Develops random set of 20 pt features (50 ft min. distance btwn pts) per class within each tile, appends to Random_Points feature class with existing domains
      ii. Updates Accuracy table in same gdb to say percent accuracy, if passing, and what features contributed

          Mark Tiles field 'Accuracy_pts_ready' "Yes"
   b. Accuracy check performed
      i. Technician will open accuracy table in 'QC_Checks.gdb' and check to see all classes have been reviewed. Classes needing review will be indicated as "Not Reviewed" or "Incomplete" in "QC_Status" column.

         \\nas-1.wvs\lulc\QC\Final_Tiles\QC_Checks.gdb\Accuracy_Table
      ii. Technician will compare points to VBMP imagery and mark fields appropriately
          1. YES/NO matches aerials
          2. Correct Classification as seen in imagery
      iii. Add comments as to what was found overall that needs correcting
          1. "Rev-water in as imperv"

          Mark Tiles field 'QC_Accuracy_complete' "Yes"
   c. Add percent accuracy to county list
      i. Technician will run Land Cover script once again to pull results from accuracy check

         \\nas-1.wvs\lulc\Scripts\QC\LULC_Accuracy.pyt\QC_Final_Tiles
         1. If passing, mark Tiles field 'Accuracy_passed' "Yes" & 'Revisions_complete' "N/A"
         2. If not passing, mark Tiles field 'Accuracy_passed' "No"
            (a) go back to Part VII Step 1 and repeat
                (i) note patterns in 'Comments' field
            (b) when accuracy passes, mark Tiles field 'Revisions_complete' "Yes"
2. <u>Tile Corrections/Revisions</u>

For this task, you will look for comments and inaccurate points to make final revisions to your tile

a. Tile Corrections
    i. Bring in iv_final & accuracy pts for tile you are working on
    \\nas-1.wvs\lulc\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\S23_38.gdb\iv_final
    \\nas-1.wvs\LULC\QC\Final_Tiles\QC_Checks.gdb\QC_s23_38
        1. Sort and look at pts that did not pass
        2. Check Tiles layer in SDE for comments field
            (a) i.e. "Rev-bad turf in the middle of forest"
    ii. Run through the entire tile and make final edits, just focusing on major corrections and issues that were found
b. Edge Matching
    i. Bring in iv_final feature classes for surrounding tiles and make edits to your tile as needed
        1. Only edit the tile you are working on
        2. Look for slivers of bad classification or major differences such as a field in as Turf in one tile and Ag in the other
            (a) Do not make edits to the other tiles, but you can add a comment on the other tile's task card or notify the technician assigned the other tile that there is an issue there

        PHASE 8 COMPLETE

3. <u>Gaps and Intersections</u>

After post-extraction & all editing complete, scripts will be run to verify accurate topology

a. Run script to create feature classes of gaps and intersections for each tile
    \\nas-1.wvs\lulc\Scripts\QC\LULC_Accuracy.pyt\Find_Gaps
    i. Creates two separate feature classes in the tile's gdb
        1. qc_gaps
        2. qc_intersections

        Mark Tiles field 'Gaps_created' "Yes"
b. Fix mistakes
    i. Technician will run through feature classes to verify any topological mistakes incurred during editing or geoprocessing
        1. Copy and paste any gap features into iv_final
            (a) Ignore slivers around edges of tiles, or features with no shape area
        2. Add CLASS_ID to all pasted features, as they appear in the imagery
            (a) May have to cut the feature up to match imagery
        3. Intersections will be taken care of when the feature class builds as raster, but you will want to check these features as well in case they show that a feature was accidentally moved during QC, or there is a very large intersect area that you want to make sure gets classed correctly in the raster conversion

        Mark Tiles field 'Gaps_fixed' "Yes"
        PHASE 9 COMPLETE

<u>X. Post Processing (per tile)</u>

***Forest/Tree analysis and exporting final raster will not execute if spatial analyst cannot be enabled*

Run Post_Processing script
\\nas-1.wvs\lulc\Scripts\Processing\LULC Processing.pyt\LULC_Processing.pyt\Post_Processing

a. Input iv_FINAL (or iv_FINAL_Lidar if applicable) feature class
   a) If the Tile was split into parts, a warning message will be raised indicated the iv_FINAL from the other part of the tile is missing (i.e. s23_05 & s23_05m)
   b) Outputs will be created in the tile's gdb on Nas

The script will run the processes indicated as follows:

1. Check Features with minimum size restrictions
   a. Extract and dissolve Hydro, Scrub, Ag, and Harvested features to check size
      i. Merge dissolved features back into tile
      ii. Select features < 1 acre
      iii. Eliminate any features to Class ID of adjacent with longest shared boundary
   b. Output Feature Class: post_eliminate
2. Subclass wetlands
   a. Extract wetland features and add values from mi_lrn_cmb to Sub Class field
      i) Run identity between wetlands and mi_lrn_cmb
      ii) Add values to field Sub Class by:
         (1) 11 = "Auto_Hydro"
         (2) 21 = "Auto_Impervious"
         (3) 41 = "Auto_Forest"
         (4) 71 = "Auto_Turf"
3. Merge Tiles
   a. If tile split into multiple parts, merge features into single tile. Otherwise skip to next step.
   b. Output Feature Class: post_merge
4. Run Forest Tree Analysis
   a. Use Raster Calculations to develop 1 acre forested areas (will first temporarily incorporate Harvested, Hydro, Scrub, Wetlands, and Ag features as 41)
      i. Select Class ID 41, export, add field 'Value' & calc to "1"
      ii. Run 'Feature to Raster' Geoprocessing tool
         1. Field: Value
         2. Output cell size: 3 (StatePlane to 1m cells)
      iii. Project raster back to 'StatePlane'
      iv. Run 'Shrink' Spatial Analyst tool
         1. Number of Cells: 36 (radius of a 1 acre circle)
         2. Zone Value : 1
      v. Run 'Cost Distance' Spatial Analyst tool
         1. Input Raster: Shrink raster output
         2. Input Cost Raster: first Forest raster output
         3. Maximum Distance: 50 (expanding Shrink to maintain the original boundaries)
      vi. Run 'Reclassify' Spatial Analyst tool
         1. Classify: 1 class
         2. output raster to values "1" & "No Data"
      vii. Run Region Group Spatial Analyst tool
         1. Input Raster: Reclass raster output
         2. Number of Neighbors: 8
         3. Zone Grouping Method: within

4. no link

viii. Run SetNull (will only leave areas with 1 acre of cells)
   1. Cell count < 4047 = "NULL"
   2. Input False Raster: Reclass raster output (changes values back to "1")

ix. Run Raster to Polygon geoprocessing tool

x. Reclass features outside as "42" Tree

xi. Output Feature Class: post_forest

5. <u>Reclassify Crop to Pasture</u>
   a. Use Identity tool to compare NASS pasture features to existing Crop features in the land cover data
      i) Export & Dissolve NASS Pasture fields and clip by tile
      ii) Export post_forest features where CLASS_ID = 82
      iii) Run Identity with post_forest as input
      iv) Calculate total acres
   b. Derive percent coverage and reclassify Crop to Pasture
      i) Calculate 2 acreage fields & recalc Identity field 'FID_NASS' where -1 to 0 acres
      ii) Dissolve Identity layer by 'FID_post_forest' & add statistics:
         (1) Acres = sum
         (2) Acres2 = max
      iii) Add a final field and calculate "Acres/Acres2"
      iv) Where value exceeds or euqals 0.75, join back to post_forest and calc CLASS_ID = 81
6. <u>Export Final Raster'</u>
   a. Convert post_merge and post_forest to raster
   b. Run a conditional with spatial analyst classifying regions in post_merge to forest/tree from post_forest
   c. Convert to polygon and run an erase and merge to add sub classed wetlands to final feature class
   d. Export to 8 Bit Unsigned .tif and add colormap of final symbology to Raster

Mark Tiles field 'Post_processed' "Yes"

<u>XI. Clip tiled Output</u>

1. For areas that overlap, do a final clip of features (originally overlapped, but left so as not to create gaps)
   a. North/South boundaries
   b. Resolution changes
   c. Flight year variation
2. Once clip is complete, or if not needed, mark Tiles field 'Tile_ready' "Yes"

PHASE 10 COMPLETE

FINAL CLASSIFICATIONS:

Water
11 – Open Water

Developed
21 – Impervious Extracted
22 – Impervious External (Local Datasets, VGIN Buildings, Lidar Buildings, Buffered RCL Dataset)

Barren
31 – Barren

Forested
41 – Forest
42 – Tree

Shrubland
51 – Shrub/Scrub

Disturbed
61 – Harvested/Disturbed

Herbaceous
71 – TurfGrass

Planted/Cultivated
81 – Pasture
82 – Cropland

Wetlands
91 – NWI/Other