Technical Plan of Operations

Virginia Statewide Land Cover Add-Ons

Spatial Corridor Analysis & Change Detection

Developed by

WorldView Solutions Inc.

www.WorldViewsolutions.com

(804) 767-1870 (p)

115 South 15th Street, Suite 400

Richmond, Virginia 23219

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1. Document Information

1.1 Document Responsibilities

Name	Organization	Responsibility
Jennifer Ellsworth, Elizabeth Garrett	WorldView	Document Development and Review
Jamie Christensen, Erik Ray	WorldView	Document Review
James Davis-Martin, Bill Keeling, Kristy Woodall	VDEQ	Document Review
Karl Huber, Roland Owens	VDCR	Document Review

1.2 Document History

Date	Version	Revisions Made
8/11/2016	1.0	Technical Plan of Operations delivered to VGIN / DEQ
9/27/2016	1.1	Updates to final 2015 change descriptions Updated delivery boundaries based on resampled 2006/2007 imagery Improved complexity of developing final classifications
10/12/2016	1.2	Updates to final vector/raster appearance
10/20/2016	2.0	Technical Plan of Operations delivered to VGIN / DEQ
10/27/2016	2.1	Reintroduce Spatial Analysis portion of project
11/21/2016	3.0	Technical Plan of Operations delivered to VGIN / DEQ
1/4/2017	3.1	Added Appendix for Detailed Workflow
1/17/2017	3.2	Updated Spatial Analysis process
2/2/2017	3.3	Changed nomenclature for 'Developed' and 'Hydro corridors'
2/3/2017	4.0	Technical Plan of Operations delivered to DEQ

1.3 Acronyms and Definitions

Acronym	Definition
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
VSLCD	VGIN Statewide Land Cover Dataset
EPA	Environmental Protection Agency
GIS	Geographic Information Systems
NAIP	National Agriculture Imagery Program
NHD	National Hydrography Dataset
TPO	Technical Plan of Operations
VBMP	Virginia Base Mapping Program
VDCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDOF	Virginia Department of Forestry
VGIN	Virginia Geographic Information Network
WorldView	WorldView Solutions Inc, Land Cover data development vendor

1.3 Project Goals

The purpose of this project is to take the developed Virginia Statewide Land Cover Dataset from WorldView Solutions and both complete a spatial analysis of hydro corridors, as well as extract a number of classes from 2006/2007 aerial imagery and perform a change detection analysis. The spatial analysis will result in a better understanding of buffered land features around the state's hydrography. The end result of the change detection analysis will be used to determine where Forest and natural habitat has been developed or changed to agricultural use, as well as where agricultural land has been developed or returned to natural land. The Technical Plan of Operations will be broken out by methodology for each of these analyses, outlining the work that will be performed to accomplish these goals.

2. Project Methodology

WorldView Solutions Land Classification and Change Detection Analysis methodology will involve the extraction of a subset of classifications for comparison with the Virginia Statewide Land Cover Dataset. An analysis will be conducted to identify where land cover has changed, and what those changes were. The following is a summarized understanding of the main tasks to be completed for this project:

- Extract 2006/2007 Forest/Natural classification
- Extract 2006/2007 Crop/Pasture classification
- Conduct 2013/2015 Land Cover change detection
- Conduct data compilation and clean-up

WorldView Solutions Land Cover Spatial Analysis methodology focuses on capturing hydro corridors and analyzing the land cover classifications within, as well as how they relate to one another. The following is a summarized understanding of the main tasks to be completed for this project:

- Delineate hydrologic corridors
- Calculate aggregated land cover classes and buffers within each corridor zone
- Define concerning characteristics of impervious features within the corridor
- Conduct data compilation and clean-up

The remainder of this section describes the specific project methodologies WorldView will implement for the completion of each portion of VGIN's land cover add-ons.

2.1 Data Development Specifications

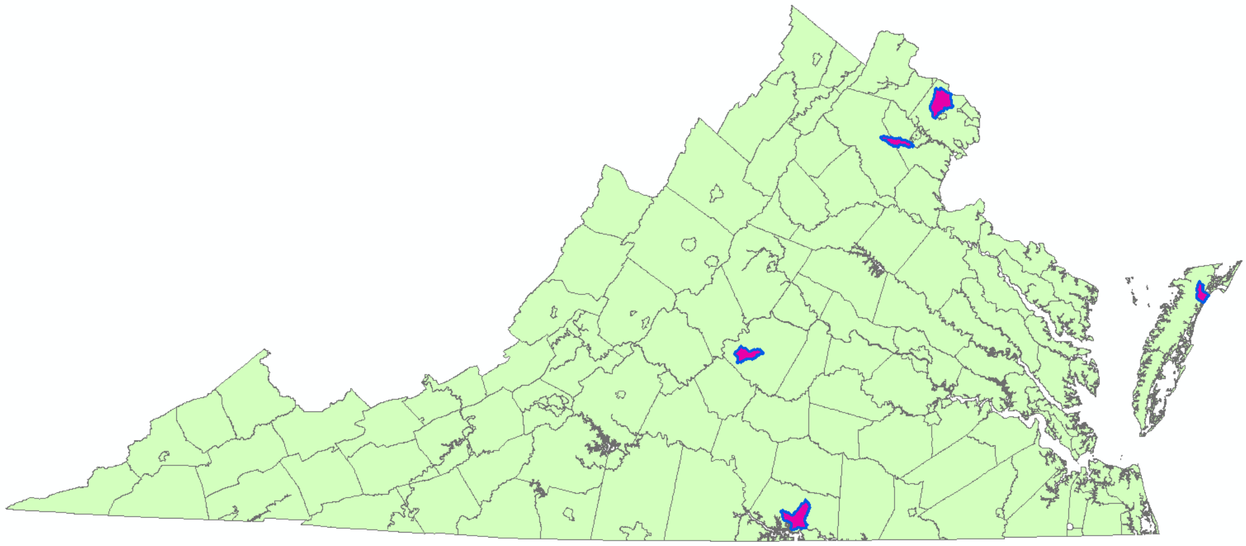
An overview of the technical workflows, processes and approach for the development of the Land Cover Spatial Analysis and Change Detection projects is provided below.

2.1.1 Pilot Project

The pilot project areas have been established to conduct change detection from particular Hydrologic Units in various localities across the state. Pilot areas were chosen first for the Land Cover Dataset to represent a number of geographical landscapes as agricultural and urban land use changes from east to west. Hydrologic Units for these analyses will follow those derived from the land cover dataset development project, excluding the area on the southwest which has not yet been developed. An additional area was added to replace the southwestern area. The pilot project areas are as follows:

Locality	Hydrologic Unit
Accomack	AO08
Fairfax	PL22
Buckingham	JM52
Mecklenburg	RL11
Fauquier	PL33

Pilot Project Localities and Hydrologic Units



Map of Pilot Project Localities and Hydrologic Units

WorldView will conduct a draft pilot delivery for each analysis, and review these deliveries with project partners. These deliveries 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.

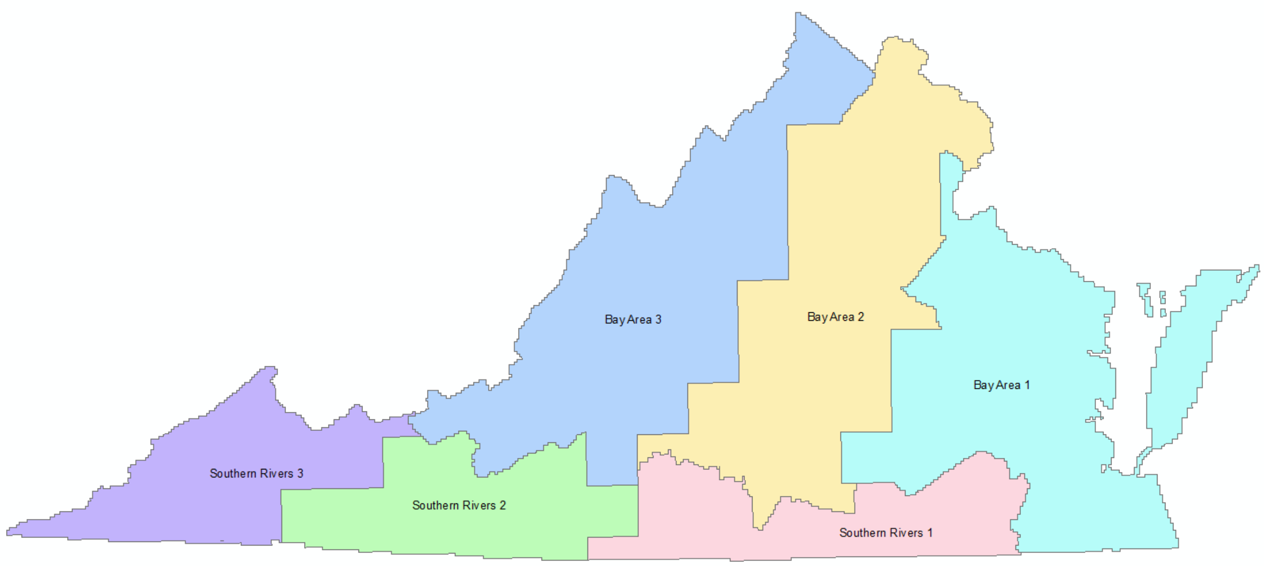
For the Land Cover Change Detection Analysis, WorldView will develop land cover extractions for Forested and Crop/Pasture classifications within each of the pilot areas. WorldView will take these polygonal areas and extract area of change by identifying classification attribution in the Virginia Statewide Land Cover Dataset (VSLCD). These outputs will be reviewed and tested for overall accuracy, and then upon a final stage of data cleanup, will be delivered as raster and vector feature depictions of change area. The overall acreage statistics for each change class (i.e. Forest to Pasture, Forest to Crop, etc) will be reported for each county.

For the Land Cover Spatial Analysis, within each of the pilot areas WorldView will develop a dataset of hydro corridors, buffered zones within each corridor, aggregated classifications across each zone, and impervious corridor feature attributes based on spatial characteristics. These attributes will include evaluating impervious features in the corridor based on proximity to hydro features, size of connected developed network, percent of impervious to pervious features in connected developed network, and slope of each feature. This dataset will be provided in vector format, along with the hydrography, while the corridor features will be delivered as raster and vector. Summarized data will be consolidated by county.

WorldView will work closely with project partners to develop recommendations for any discrepancies found after the draft reviews. After resolving any reported issues, WorldView team members will review feedback, communicate intended resolutions to additional discrepancies, and integrate the resulting changes. After all modifications have been resolved to the satisfaction of the project partners, WorldView will provide the project partners with the Final Pilot Project Delivery for each analysis. This will include all deliverables created during the Pilot and Draft phases and final copies of any documentation developed for the project.

2.1.2 Deliverable Areas

Six Deliverable Areas were established for the land cover development project, with the majority of land in the first three areas based on the request to develop the Chesapeake Bay watershed counties before the Southern Rivers counties. By partitioning the regions into a total of six deliverable areas, progress tracking and extraction tasks were managed more efficiently. The Chesapeake Bay watershed counties will again be delivered ahead of the Southern River counties. However, the delivery areas for these two analyses have been slightly altered to match the boundaries of the older VBMP imagery used in the project. The six delivery areas are as follows:



Project Delivery Areas

The calculated size of each deliverable area is as follows:

Delivery Area	Square Miles
Bay Area 1	9,754
Bay Area 2	9,745
Bay Area 3	10,037
Southern Rivers 1	4,168
Southern Rivers 2	4,266
Southern Rivers 3	4,329

Project Delivery Area Size in Square Miles

2.2 Land Classification and Change Detection Analysis Technical Approach

2.2.1 Compile Source Data

The following datasets were compiled to support the development of 2006/2007 forested and agricultural classifications:

- Virginia Base Mapping Program imagery (VBMP) 2006/2007
- Virginia Department of Transportation (VDOT) RCL 2012 Q3

*Previous datasets had inaccurate centerline features, and were missing CLASS information for buffering the center-line

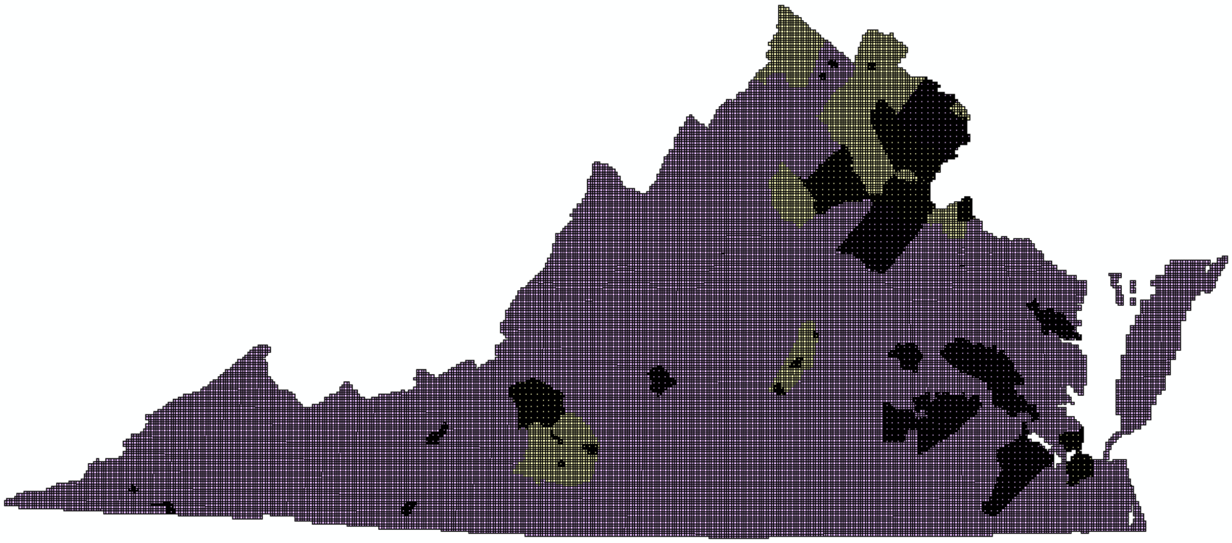
- National Land Cover Database (NLCD) 2006
- National Ag Imagery Program (NAIP) 2006/2008
- National Agricultural Statistics Service (NASS) 2008
- Virginia Department of Forestry (VDOF) Land Use & Forest Cover 2005

These data layers will be used as a reference during cleanup and QC of extracted land classifications.

2.2.2 Prepare Imagery

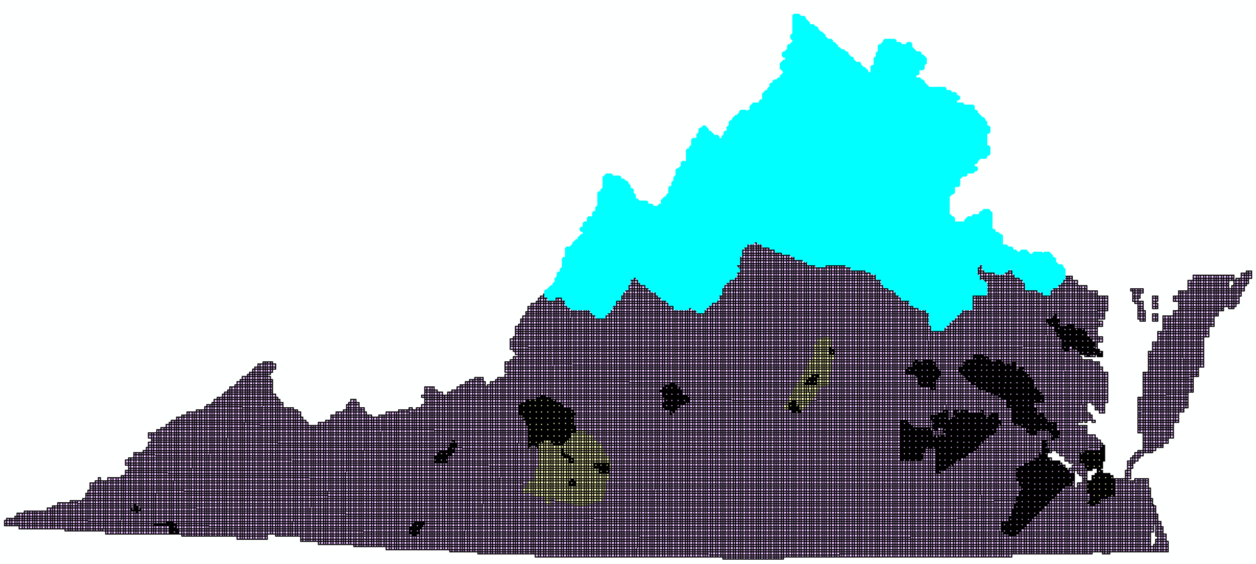
Imagery will be collected for the years of 2006 and 2007 for the change detection analysis. The entire state will be divided into sub-regions for classification based on a combination of VBMP flight data and additional spectral variation identified by WorldView's Imagery Analysts. The following fluctuations in spectral output have assisted in defining such boundaries as follows:

- **Year of imagery collection ranges between 2006 and 2007**. Spectral variation between the different flight dates creates the necessity to break these two areas apart during processing. Separate training samples will need to be developed for each of these regions
    - 2006 areas represent a smaller portion of the state than the 2007 flight
    - Area in purple is 2007 imagery, which will be used when the years flown overlap, and 2006 is the remainder in yellow:



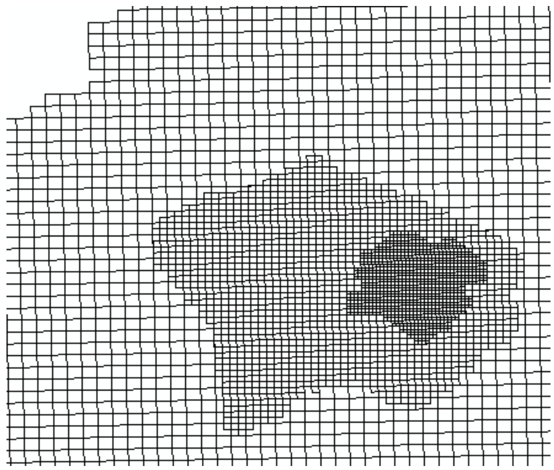
VBMP 2006 and 2007 Imagery Collection Areas

- **Northern versus southern coordinates**. The tiles produced in the 2006/2007 VBMP Imagery have overlap where the North and South State Plane coordinate systems differ. The imagery for each year will be split and processed separately as NAD 1983 Virginia State Plane North FIPS 4501 (US Feet) and the NAD 1983 Virginia State Plane South FIPS 4501 (US Feet) coordinate systems to ensure there are no data gaps in the outputs. 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 Southern area for each year:



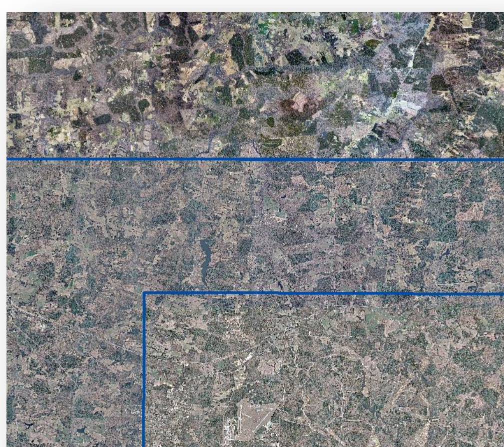
NAD 1983 Virginia State Plane North FIPS 4501 (US Feet) Area highlighted

- **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 majority 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.



Grid example of differing VBMP Tile pixel resolution

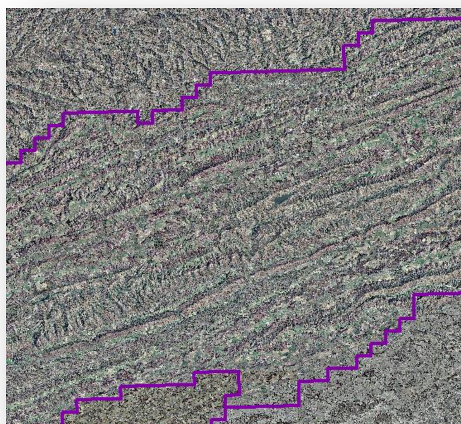
- **Additional spectral variation (hue and saturation)**. Additional spectral variation exists between areas that were not initially identified. These areas are usually very flat boundaries across the state that can easily be distinguished Additional boundaries will be created between remaining areas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



Example of 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:



Example of Geographic Region variation

2.2.3 Feature Analyst Extraction

Image extraction software will be utilized to develop a Forested classification and a Crop/Pasture agricultural classification. 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 and then subjected to a series of automated cleanup scripts and manual editing. These steps are detailed in the following sections.

2.2.3.1 Create Training Data

A series of training data sets will be created, using field and "screen" verified data samples, for each of the two 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 shapefiles, and will be represented as a compilation of vector features for each land cover type. The number of samples that can be directly input into the training sets for land cover extraction will depend on the project area.

Example of training sample inputs for Feature Analyst image extraction

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:

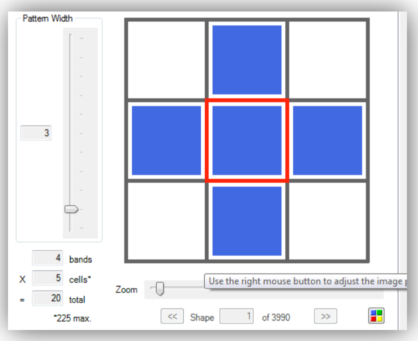
- Full spectral variety included in sample features
- Varied orientation of polygon features representative of ground coverage
- Samples digitized to encompass entire feature and distinguish edge of classification change

Example of variation in orientation and distinguishing edges in training sample inputs

The final training input layers will be used for Supervised Learning feature extraction.

2.2.3.2 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.



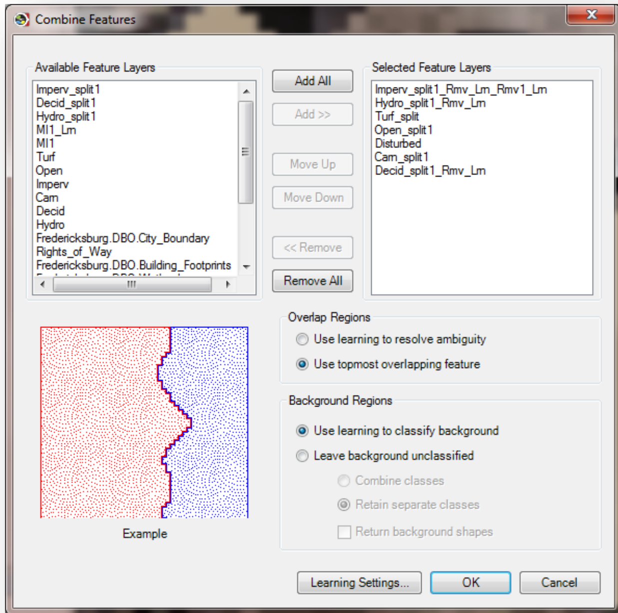
Example of Input Representation parameters for feature extraction

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. 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.

2.2.3.3 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.



Example of Feature Analyst Supervised Learning settings

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. 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.

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.

2.2.3.4 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.

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. The methodology behind script automation refines further as new regions are developed that introduce unique features, such as forest shadows in the mountains. The Tree extraction scripting that was developed against the 2013/2015 Forest data will be applied for the Forest classification in the 2006/2007 development. An algorithm similar to that used on the land cover dataset will be applied, where Spatial Analyst tools remove all features that do not fit a 1-

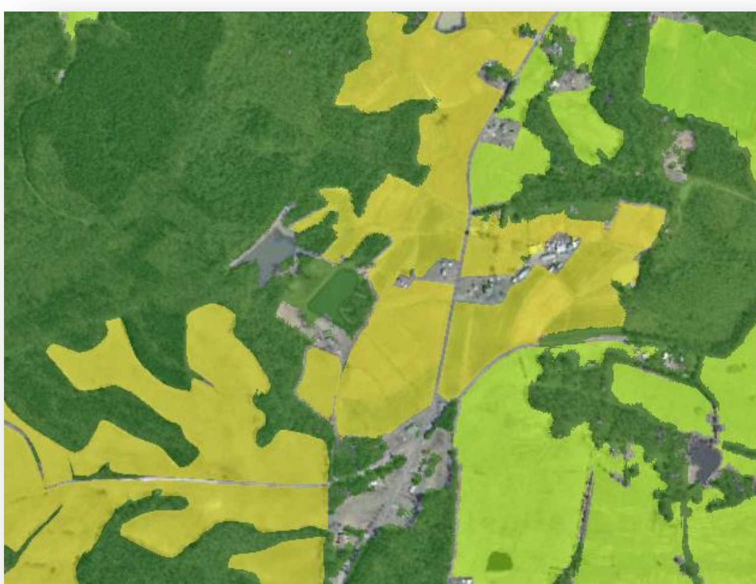
acre buffered area. The Agriculture class will also have a 1-acre minimum size applied, so any features extracted from the image classification software will be eliminated if they do not meet that threshold. Where those features are bordered by larger features, the smaller will dissolve based on the classification of the feature with the largest shared border.

A significant amount of manual data clean-up will need to be performed as part of the project to differentiate some of the features that were not identified correctly based on spectral signature alone. This will be accomplished through visual inspection against statewide imagery, with reference to external datasets such as VDOF forest cover and NAIP imagery.

2.2.3.5 Develop Classifications

At this point in the extraction process, where Feature Analyst classification output has been cleaned up using automated processes and manual editing, the two developed classes used for change detection will be finalized.

In the previous step, many classes were created to encompass all of the various characteristics of each set of land cover features, which will be merged at this step. An example of this would be the combination of coniferous and deciduous forest outputs into the overall Forest classification. The Agriculture output will be classified as either 81 for Pasture, or 82 for Cropland, through the identification of characteristics reviewed by imagery analysts. The National Agricultural Statistical Survey data will also be used as a reference to differentiate these two classes. Additional post-processing steps taken to reach the final output include running ESRI geoprocessing tools to eliminate outliers, filling sliver areas by identifying where buffered forest intersects other features, and checking for data gaps due to the processing of very large and complex features. Once any gaps or overlaps are properly identified and corrected in the data, both the Pasture/Crop and the Forest datasets will be at a finalized state to be utilized in the change detecting analysis.



Sample combined Forest and Agriculture dataset

2.2.4 Change Detection Analysis

With the Forest/Natural and Agricultural land classifications extracted, an overlay analysis will be performed to derive where land cover has changed. For the 2006/2007 Forested class, it is of importance to determine where the features have changed to water, agriculture, or developed. For the 2006/2007 Crop/Pasture class, it is of importance to determine where the features have changed to water, forest, or developed. Due to some classifications being consolidated for the 2006/2007 extraction, there are many class IDs listed for the forested 2013/2015 classification. Additionally, there will also be no indicator of change when Tree is overlaid with the 2006/2007 extraction due to the lack of LiDAR availability and 4-band spectral imagery. The breakdown of classifications is as follows:

<table>
<tr><td rowspan="7">Classification Categories</td><th colspan="2">2006/2007 Land Cover</th><th>LCCD class_ID</th><th>2013/2015 Change Areas</th><th>VSLCD class_ID</th></tr>
<tr><td rowspan="3">Forested</td><td rowspan="3">Forest, Woody Wetlands, Harvested, Scrub</td><td rowspan="3">40</td><td>Water</td><td>11</td></tr>
<tr><td>Developed</td><td>21, 22, 31, 71</td></tr>
<tr><td>Agriculture</td><td>81, 82</td></tr>
<tr><td rowspan="3">Agricultural</td><td rowspan="3">Crop, Pasture</td><td rowspan="3">81, 82</td><td>Water</td><td>11</td></tr>
<tr><td>Developed</td><td>21, 22, 31, 71</td></tr>
<tr><td>Forest</td><td>41, 51, 61, 91</td></tr>
</table>

Table of classifications used for Land Cover Change Detection Analysis

The analysis will intersect the 2013/2015 VSLCD classifications with the extracted datasets from the 2006/2007 imagery, and report where the features have changed, and to which category these changes fall under. The land cover comparison analysis will be accomplished through the process of running ESRI Geoprocessing and Spatial Analysis tools, and calculating statistics on vector outputs. The VSLCD classifications will not be altered, but will be categorized so that only the specific classifications of concern will be described as a change. Where VSLCD classifications of 11, 21, 22, 31, 71, 81, or 82 intersect the 2006/2007 LCCD classification of 40, a change will be identified. Where VSLCD classifications of 11, 21, 22, 31, 41, 51, 61, 71, or 91 intersect the 2006/2007 LCCD classification of 81 or 82, a change will be identified; the CLASS_IDs 41, 51, 61, and 91 more closely represent the 2006/2007 forest class, so will be considered a change from agriculture to forested. The final CLASS_ID field for the overall comparison will be a concatenation of the 2006/2007 and 2013/2015 classifications respectively. All classification combinations not listed above will be considered "no change", and will not appear in the final dataset.

Another automated cleanup step will be introduced at this time to address sliver features that appear as change in the final comparison. Many of these features are greater than once acre in size, so they do not meet the criteria to be eliminated in previous steps, but are not wide enough to be a true indicator of change. The majority of such features are due to difference in imagery between years, that creates feature borders of similar classifications that do not exactly align. To ensure that these slivers of incorrect classification change are no longer represented, Spatial Analysis tools will be implemented that apply majority statistics to a set of neighboring cells. The resulting CLASS_IDs will be used for the final indicators of change.

There will be an additional attribution that identifies the acreage of change to each classification, which will be provided in excel format. This will be reported overall for each county in the state, and additionally by HUC as requested.

County\City	Change Code	Change Type	Acres
Accomack	8111	Agriculture to hydro	1.02
Accomack	8231	Agriculture to developed	12.39
Accomack	8251	Agriculture to forest	19.75
Accomack	4011	Forest to hydro	2.26
Accomack	4022	Forest to developed	71.23
Accomack	4082	Forest to agriculture	20.15

Example of overall acreage calculation per change, by County

Final processing for the change detection analysis will be completed by VBMP tiled boundaries, and delivered in raster and vector format. A symbology layer representing the final change indicators will be provided for the vector datasets, and a matching colormap applied to the raster datasets.

Symbology representing descriptions of feature changes over time

2.2.5 Classification Definitions

The following classification definitions will be used to determine which features are included in the two developed classifications of the 2006/2007 BMP land cover extractions.

2.2.5.1 Forested

This classification includes areas characterized by tree cover of natural or semi-natural woody vegetation as defined by the EPA. This class includes deciduous, evergreen, and mixed foliage types, as well as areas that would have been otherwise classified as Harvested or Scrub/Shrub in the VSLCD, as long as the area consisted of grass or ground cover surrounded by forest. Additionally, any areas that would fall under Woody Wetlands categorization in the TMI/NWI would also fall into this classification.

Additional methods will be applied to ensure that the area delivered does not include small isolated trees in the analysis. A minimum buffer size of 1 acre will be applied to the extracted regions, where smaller features will be removed from the output using a raster Spatial Analysis algorithm. VDOF forested cover will be reviewed against the outputs to determine where areas were misclassified.

Example of Forested classification

2.2.5.2 Cropland

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. Examples include row crops, small grain, fallow (tilled with sparse vegetative cover), feeding operations, orchards, groves, vineyards, nurseries, and other horticultural areas. The features included in this classification will be 1 acre or more in size.

Cropland 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. Outputs will then be reviewed with the available reference data to ensure that all fields were captured and not misclassified. This process will involve manual data clean up, as large public and recreational fields (airports, schools, etc) will need to be removed from the output.

Example of Cropland classification

2.2.5.3 Pasture

This classification includes areas characterized by grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops as defined by the EPA. The features included in this classification will be 1 acre or more in size. Any grasses that fall into these descriptions that cannot be identified as recreational or otherwise non-agricultural will be included here if the land is greater than 1 acre in size.

Similar to Cropland, 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. Outputs will then be reviewed with the available reference data to ensure that all fields were captured and not misclassified. This process will involve manual data clean up, as large public and recreational fields (airports, schools, etc) will need to be removed from the output.

2.3 Land Cover Spatial Analysis Technical Approach

2.3.1 Compile Source Data

The following datasets were compiled to support the spatial analysis portion of this project:

- Virginia Base Mapping Program imagery (VBMP) 2013/2015
- Hydrography (National Hydrography Dataset - NHD)
- VGIN Digital Terrain Model (DTM) (2013/2015)
- VGIN Statewide Land Cover Dataset (2013-2015)

These data layers will be used as a reference to determine the location of spatial corridors, as well as in determining concerning factors such as slope on impervious features within these corridors.

2.3.2 Prepare Land Cover Datasets

2.3.2.1 Establish Hydrography

Before extracting the hydro corridors, hydrography data from the land cover dataset and various external resources needs to be combined. First, the Virginia Statewide Land Cover Dataset (VSLCD) water classification will be pulled out of each tiled feature class. Secondly, the VSLCD external hydro datasets will be used, which were delivered with the product as a tiled output of NHD polygonal features, TMI hydro polygons, and NHD flowlines. Flowlines were buffered into 15 foot polygons and merged with the other water features.

To complete the hydro input for this portion of the project, the hydro overlay and extracted water features from the land cover dataset will be merged into a final generalized dataset. This dataset will delineate where the 150 foot corridors will be extracted from the land cover dataset.

Example of combined Hydro dataset

2.3.2.2 Derive Elevation

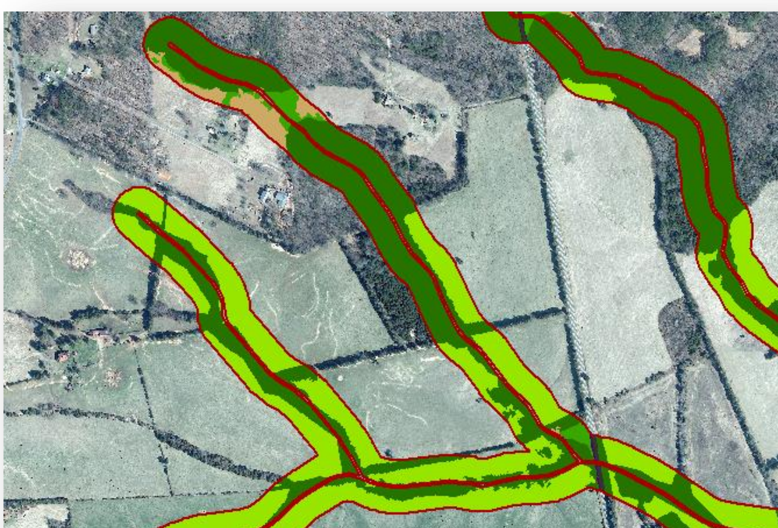
For the impervious portion of the analysis, one of the concerning factors will be based upon slope of features. Digitial Terrain Model (DTM) elevation data will be extracted and combined for each area, providing elevation values at a 3-meter overall resolution. In order to use these elevation datasets, the raster data will first need to be mosaicked for North and South areas of the state. Worldview will automate the creation of these mosaic datasets using ESRI Geoprocessing, and overlay the final rasters with the centroid points of each impervious feature to determine slope.

2.3.3 Develop Corridors

Once hydrography datasets are merged and available in tiled boundaries, 150 ft corridors will be extracted surrounding these features. Additionally, a set of 35 ft, 50ft, and 100 ft zones will be partitioned out and divided at 5 ft intervals. Each individual feature in these zones will be classified with the predominant feature within and dissolved with similar features surrounding them. The final classification will be used to determine areas of buffer or non-buffer natural land cover classifications.

2.3.3.1 Delineate Hydro Corridors

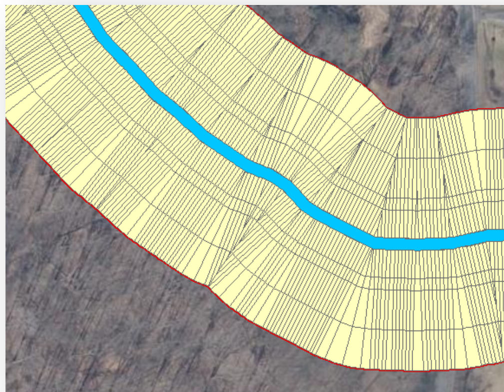
A dissolved set of 150 ft corridors for each tile will be delineated around the merged hydro dataset from the Virginia Statewide Land Cover Dataset water features and hydro overlay features. This will be accomplished using ESRI geoprocessing buffer tools, and then the output will be used to extract the underlying land cover classifications from the Virginia Statewide Land Cover Dataset. The developed 150 ft corridors will be fully covered based on the generalized classifications of the VSLCD values, while the final dataset will result in a variety of size outputs dependent on connectivity of hydrologic features. These areas will be used to determine buffered and non-buffered acreage of Crop, Pasture, Developed, Roads, and Natural areas within each county in the state.



Extracted corridor represented in red, with underlying classification from the Virginia Statewide Land Cover Dataset

2.3.3.2 Subdivide Corridor Zones

A set of corridor zones will be extracted within the hydro corridors. The zones will represent where land cover classifications are or are not buffered, and the predominant classifications within each zone along the corridor. To create this data, Worldview will develop a set of scripts that utilize ESRI geoprocessing tools to automate an extraction of Theissen polygons that break the stream corridor into small manageable zones around 5 feet in width.



Breakdown of hydro corridors into 5 foot features, subdivided at various zones

Each feature will also be broken parallel to the corridor at 35, 50, and 100 feet upland of the hydro dataset. When the predominant classes are derived for these features, these upland zones will help determine where the classes of Crop, Pasture, Natural, Developed and Road are occurring in relation to the hydro features.

For each Theissen output feature, the VSLCD dataset values will be overlaid to extract classification IDs. Where there are multiple classifications, the predominant class will be extracted and used to determine the overall classification. Some classifications from the land cover dataset will be combined to generalize where zones are Developed, Crop, Pasture, or Natural, while Virginia’s Road Centerline data will be used to categorize features as Road.

Representation of final buffer zones when classified features get dissolved

To determine the Developed classification, the land cover classifications of impervious, barren, and turf that intersects impervious will be combined. Additionally, with buffered RCL data merged into the Land Cover data, those features that are predominantly covered by the buffer will be reclassified as Road. Any leftover turf, along with forest, tree, wetland, scrub, and harvested features will be considered Natural. Crop and Pasture are retained from their original values.

All final values will be dissolved by classification type within each zone. Where Natural features are the predominant classification, and uninterrupted by the other classes, from the start of the first 35-foot upland zone an additional buffer attribute will be assigned with that zones value. As the Natural buffer continues to dominate each zone, an additional attribute will be assigned that identifies that zone. These buffered attributes can be used to identify totals for buffered land across the state. The final areas will be delivered in polygon format.

Final corridor dataset, with each zone attributed by the dominating class of Crop, Pasture, Natural, Developed, or Road

2.3.4 Characterize Impervious Values of Concern

The final spatial analysis will be applied to impervious features that are within the hydro corridor. These features are identified from the extracted and external impervious datasets of the Virginia Land Cover Dataset, and then subdivided to only those features that intersect the developed 150-foot hydro corridors. Each feature will be attributed on a number of factors identified as influential in determining concerning characteristics of impervious areas. Features in the corridor will receive values for categories related to slope, developed feature connectedness, and proximity to water features. The following sections outline these categories and how they will be derived.

2.3.4.1 Calculate Hydro Proximity

The first factor in the impervious characterization will be based on the proximity of the feature to the closest hydro within the corridor. A distance value will be derived from a near distance calculation applied to the feature, where the closest point of the hydro feature is measured to the closest point of the impervious feature. This data will be added as an attribute in feet.

Impervious features (purple) within 150 feet of hydro (blue)

2.3.4.2 Measure Slope

The second factor in the impervious characterization will be based on slope of the impervious feature. The value will be derived by determining the slope of the centroid of the impervious feature, which will represent the average slope of the feature. To determine slope, elevation data from VGIN DTM datasets will be used. The most recent dataset is at a 3-meter resolution. The slope degree value will be derived and added as an integer attribute.

Slope raster values from DTM represented in stretch symbology

2.3.4.3 Determine Size of Developed Network

The third factor in the impervious characterization will be based on overall size of the developed network that the impervious feature is a part of. To derive this data, all impervious and intersecting turf features in and outside of the corridor will be analyzed for connectedness. Road centerline buffers will be erased from this data to distinguish between distant networks that otherwise would be considered as one network due to an intersecting road. With the road buffers removed however, the close impervious and turf features on each side of the road would be considered separate networks. To regain the connectedness of these closer features, all areas will be buffered by 75ft and dissolved to determine final areas of connectedness. Overall acreage of the combined impervious and pervious turf for each network will then be calculated. An overlay analysis will apply the acreage values to each impervious feature within the corridor.

Example of developed feature networks derived with road buffers removed

2.3.4.4 Determine Percent Impervious of Developed Network

The fourth factor in the impervious characterization also is related to the identified developed network area that intersects each impervious feature. While overall size was determined in the developed areas for the previous attribute, an additional value will be derived that determines the percent of imperviousness in each developed area. Acreage of imperviousness will be compared to the overall acreage and percent derived.

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 the changes detected and delivered between the 2006/2007 and 2013/2015 imagery, both automatically and manually. This data comparison will be conducted by extracting change from the output, then completing the analysis looking at each of the VBMP imagery sets side by side. Imagery Analysts will review the results to locate anomalous features and identify possible changes to learning parameters within that class.

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 National Ag Imagery Program data, and the National Agricultural Statistics Service data. As more datasets are identified, they will be incorporated into the final process for developing quality control.

The finalized Land Cover change data will be merged into a single feature class and a single raster output for each VMP tiled imagery area. This feature class and the raster output will be delivered in one meter formats, for each delivery area. The areas of change will also be delivered as a separate set of data, similar to the above mentioned formats.

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 Deliverable	Schedule
1	Classification/Change Pilot Final Delivery	10/10/16
2	Revised Technical Plan	11/18/16
3	Classification/Change 1st Area Draft Delivery	1/16/17
4	Spatial Analysis Pilot Final Delivery	1/25/17
5	Spatial Analysis 1st Area Draft Delivery	2/17/17
6	Spatial Analysis 2nd Area Draft Delivery	3/9/17
7	Classification/Change 2nd Area Draft Delivery	3/16/17
8	Spatial Analysis Bay Areas Final Delivery	4/28/17
9	Spatial Analysis Southern Rivers 1 Draft Delivery	5/11/17
10	Classification/Change 3rd Area Draft Delivery	5/16/17
11	Spatial Analysis Southern Rivers 2 Draft Delivery	6/7/17
12	Classification/Change Bay Areas Final Delivery	6/15/17
13	Spatial Analysis Statewide Final Delivery	6/28/17
14	Classification/Change Southern Rivers 1 Draft Delivery	7/6/17

15	Classification/Change Southern Rivers 2 Draft Delivery	8/18/17
16	Classification/Change Statewide Final Delivery	9/9/17

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. These meetings will 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

The ArcGIS Online Group created for the 2013/2015 Land Cover project on the WorldView Organizational Account will be used to share project status on a bi-weekly basis to correspond with the bi-weekly status report. All project stakeholders have been invited to the group, and we will add any additional reviewers as requested. Those without ArcGIS Online accounts can 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 complete

Appendix A: Detailed Technical Workflow

<u>Statewide Land Cover Add-on Analyses- Technical Workflow</u>

<u>KEY:</u>
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

CHANGE DETECTION

<u>I. Preliminary Tasks</u>

1. <u>Data Acquisition</u>
   a. VBMP Imagery for correct year(s) (2006, 2007)
      i. Located on external drives \\artie-pc\J:\2006_tifs and \\artie-pc\I:\2007_tifs
   b. VBMP Tile grid for correct year(s) (2006, 2007)
      i. Divide Tile Grids into two separate shapefiles based on projection, NAD_1983_StatePlane_Virginia_North (US Feet) or NAD_1983_StatePlane_Virginia_ South (US Feet) (ex. N16_79 is in north, s13_86 is in south. “Grid” attribute field contains this data)
      ii. Dissolve the tiles based on grid code and year, store outputs in \\LULC-WS-2\vgin\LCA\Reference folder as “Tiles_North” and “Tiles_South”.
   c. VBMP RCL Centerlines 2008 Q1
      i. Break into delivery areas & North/South, store outputs in \\LULC-WS-2\vgin\LCA\Data_Downloads\RCL\By_Tile
   d. NASS raster 2008
      i. GIS Service
      http://gismaps.vita.virginia.gov/arcgis/services - VBMP years
2. <u>Imagery Tiling</u>
   a. Run “Resample Imagery” script in \\LULC-WS-2\vgin\LCA\scripts\LCCD.pyt\ResampleImage
      i. “Tiles_North” or “Tiles_South”
      ii. Output folder VBMP_Imagery
         a. Creates GDB based on projection, year, and scale the imagery is based on (ex. North_2007_100)
   b. Run Clip_imagery script in \\LCCD\Scripts\Imagery folder.
      i. Need to change code to reflect which delivery area you are clipping to

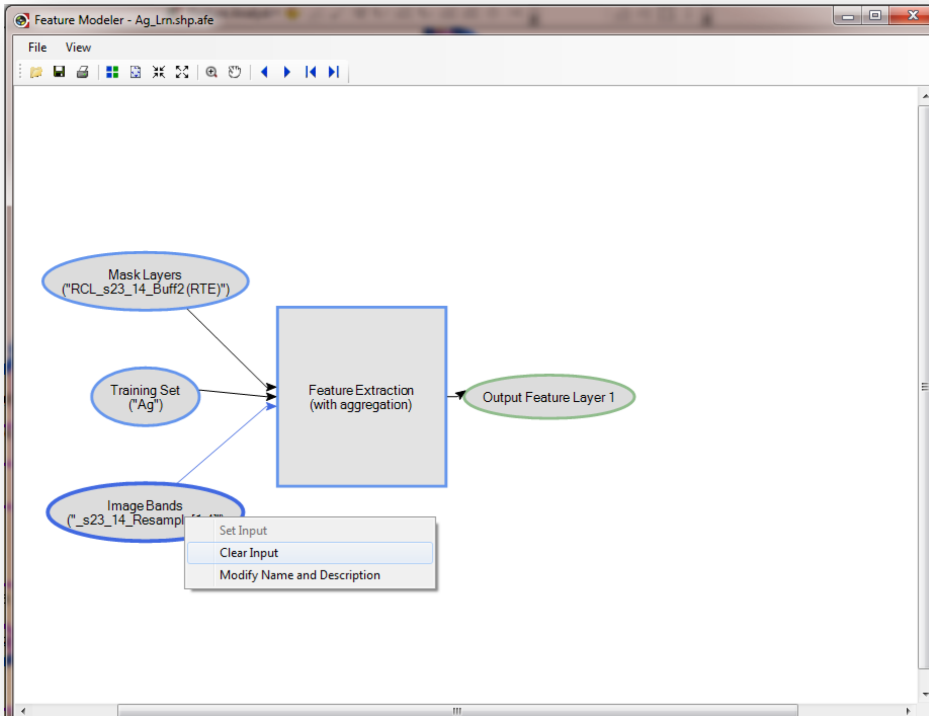
3. <u>VBMP RCL Attribution</u>
   a. Run Feature to Point geoprocessing tool to create centroid points from RCL centerlines
      i. Check to create “inside feature”

b. Buffer 2014 Q1 export of Navteq centerlines by 25ft
    i. Dissolve Type: None
c. Run Spatial join to add Navteq attribution to RCL centroid pts
    i. Target: RCL pts
    ii. Join: Navteq Buffer
d. Join RCL Spatial Join points to RCL centerlines based on 'RCL_ID'
e. Calculate new 'LANES' field as an addition of Navteq 'TO_LANES' & 'FROM_LANES'
f. Calculate new 'NAV_FUNC' field from Navteq Functional Class
g. Remove Join
h. Create final 'BUFFER' field based on the following:
    i. NAV_FUNC = 5 and VDOT_FUNC= <Null>, LANES=1
    ii. NAV_FUNC = 5 and VDOT_FUNC IS NOT <Null>, LANES=2
    iii. NAV_FUNC = 1 and VDOT_FUNC= <Null>, LANES=1
    iv. NAV_FUNC = 1 and VDOT_FUNC IS NOT <Null>, LANES=2
    v. Then BUFFER = LANES * 2 (based on 1 lane being 12 ft, which is 4 meters, and the buffer being half the meters)
i. Save final buffers
   \\LULC-WS-2\vgin\LCA\Data_Downloads\RCL\RCL_2012\By_YearDelivery

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

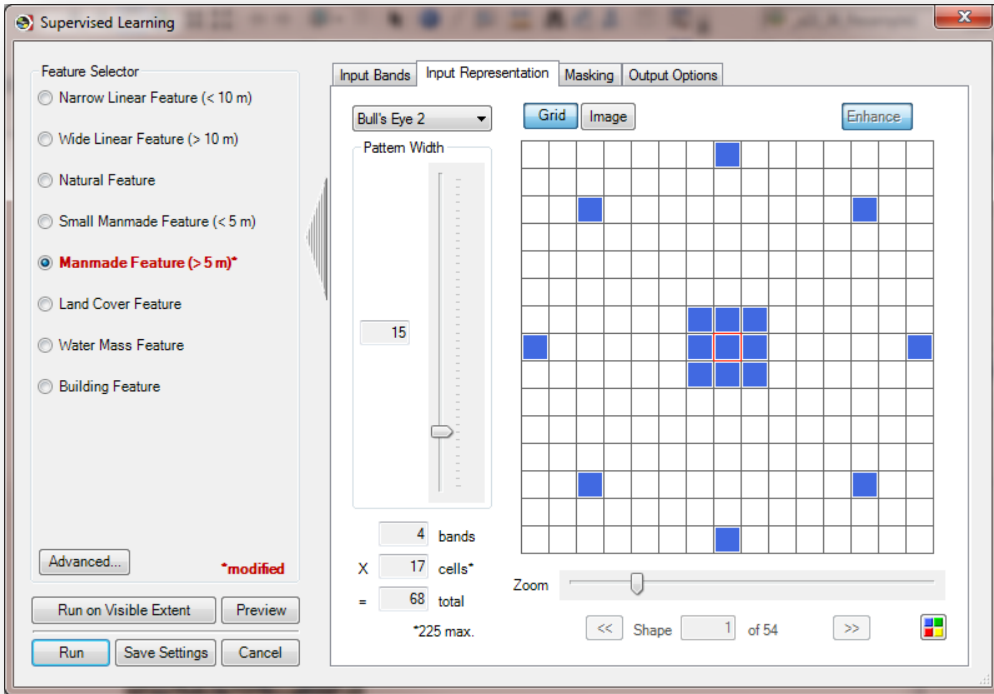
1. <u>Create Training Samples</u>
   Will be completed for one tile within each specified Mosaic Area developed (will batch process to other tiles within)
   - Ag
   - Brown
   - Coniferous Forest
   - Deciduous Forest - Brown
   - Deciduous Forest – Dark/Shadow
   - Deciduous Forest - Green
   - Green
   - Hydro
   - Impervious
   - Yellow
2. <u>Run Learning Pass, then cleanup, on single classes</u>
   (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 reviewing Ag_Lrn and MI_Lrn
   a. Ag
      \\Artie-pc\vgin_LCA\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)

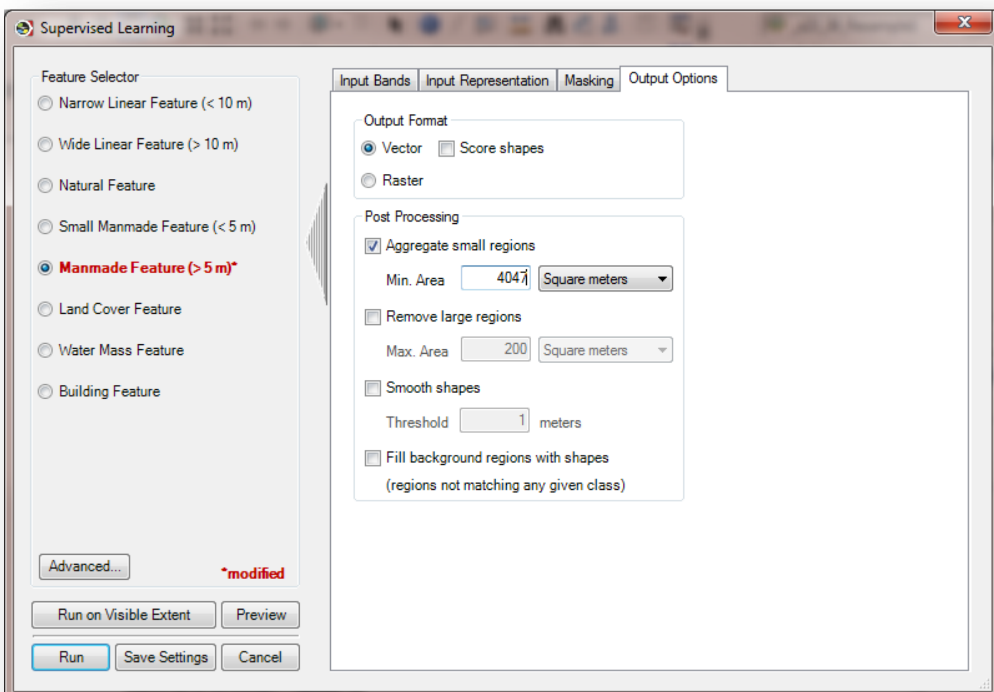
- RUN model



*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\Old_VBMP
ii. Bring in 2012 RCL Buffer
\\lulc-ws-2\vgin\LCA\Data_Downloads\RCL\RCL_2012\By_YearDelivery
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_LCA\Processing\Bay1\B1_2013_South_1\s23_38\
    Ag_Lrn
    Mark Tiles field ‘Ag_Lrn’ “Yes”

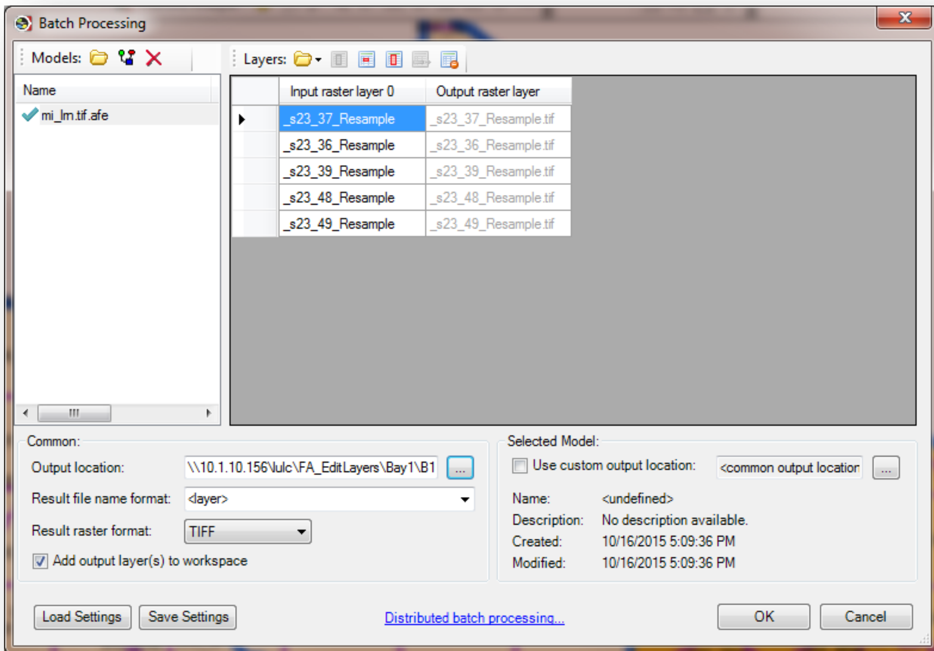




*These images represent Ag settings for Supervised Learning feature extraction

3. <u>Create Multi-class Input layer from all remaining classes</u>
(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 reviewing MI_Lrn for accuracy
[\\Artie-pc\vgin_LCA\Processing\Bay1\B1_2013_South_1\s23_38\MI_Lrn.tif.afe](\\Artie-pc\vgin_LCA\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



*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
    - DecidBrown
    - DecidDark
    - DecidGreen
    - Green
    - Hydro
    - Impervious
    - 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_LCA\Processing\Bay1\B1_2013_South_1\s23_38\MI_Lrn.tif

ii. When complete, review MI_Lrn and Ag_Lrn for accuracy
    1. If classifications reflect the VMP imagery well,
       Mark Tiles field 'MI_Ag_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_Ag_passed' "No"
          When a new output passes, mark Tiles field 'MI_Ag_fixed' "Yes"
          'PHASE' = 1 Complete

III. Layer Processing

1. Wait for Ag_Lrn & MI_Lrn.tif to be ready
   a. Can check folders in \\Artie-pc\vgin_LCA\Processing for data, and make sure that Tiles_AddOn field 'MI_Lrn_fixed' is marked as "Yes"
2. Copy data layers to LULC-WS-2
   a. Create a copy of the Ag_Lrn.shp and MI_Lrn.tif layers from \\Artie-pc\vgin_LCA\Processing to \\LULC-WS-2\vgin\LCA\LCCD\FA_EditLayers in the matching folder
3. Run GeodatabaseIntegrate/Class/Combine/DetectLrn script for each tile
   a. Creates a new geodatabase with tile name in \\LULC-WS-2\vgin\LULC\FA_EditLayers folders

\\lulc-ws-2\vgin\LCA\LCCD\scripts\LCCD.pyt\GeodatabaseIntegration/ClassCombine/DetectLrn
      Could take 4-30 hours
   b. Integrate Forest and Ag
      i. Exports 'Ag_Lrn.shp' to 'Ag_Lrn' feature class to the scratch gdb
      ii. Exports 'MI_Lrn.tif' to 'lulc' feature class to the scratch gdb
         1. Converts CLASS_ID 1, 6, 9 to "Non-Forest", CLASS_ID 80
         2. Converts CLASS_ID 2, 3, 4, 5 to "Forest", CLASS_ID 40
         3. Converts CLASS_ID 7 to "Hydro", CLASS_ID 10
         4. Converts CLASS_ID 8 to "Impervious", CLASS_ID 20
      iii. Dices CLASS_ID 40 Forest
         1. Creates new 'Forest_Lrn' feature class in the scratch gdb
         2. Recalculates any null CLASS_IDs from Forest_Lrn to 40
   c. Combines forest and ag features into a single feature class, 'ForestWAg'
      i. Overlays ag onto forest
      ii. Dices and dissolves layer into single part features
      iii. Eliminates holes less than 1525 square ft in area
   d. Runs overlay analysis on forest features
      i. Buffers forest in forestWAg layer out by 150ft and dissolves buffer into single part features
      ii. Classifies buffer by proximity to ag:
         1. Where buffer intersects ag, assign class 48
         2. Where buffer with class 48 intersects empty space, assign class 47
         3. Where buffer with class 48 intersects forest, assign class 46
      iii. Creates new 'ForestAg' layer, converting class 46 to 40 and removing classes 47 and 48

iv. Eliminates features <1 acre on new ForestAg layer
    1. Runs polygon neighbor analysis to find largest shared neighbor
    2. Assigns class_id of largest shared neighbor to feature
    3. Creates new ForestAg feature class in the gdb

e. Runs overlay of 2013/2014/2015 LULC raster with a raster export of ForestAg
    i. Project raster back to 'StatePlane'
    ii. Runs focal statistics on final raster to remove misclassified sliver features of change due to different angles and season of imagery
    iii. Add new field with combined values for before (2006/2007) and after (2013/2014/2015) classification
        1. E.g., "8241" would be crop that changed to forest

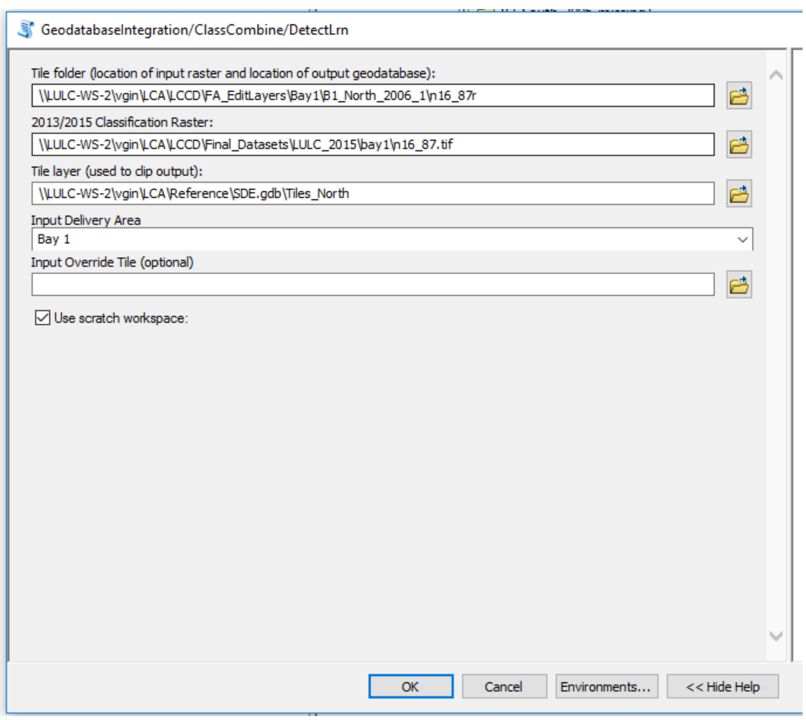
f. Adds final description field that pulls values from external table

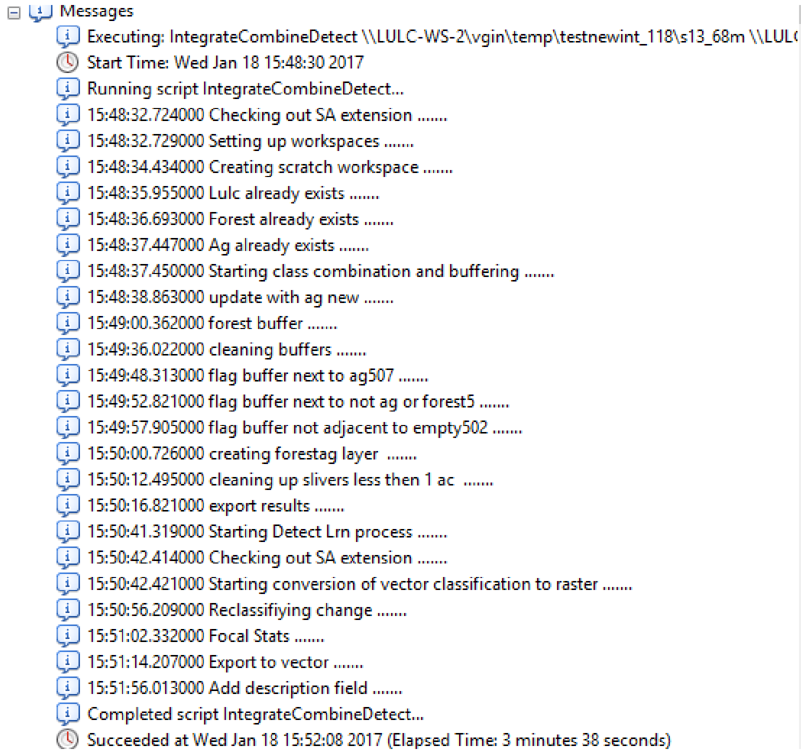
g. Saves as 'Detect_Lrn' in geodatabase

\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\Detect_Lrn

h. Creates an empty 'Change_AOI' feature class to the geodatabase

\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\Change_AOI





Mark Tiles field 'Detect_Lrn' "Yes"
'PHASE' = 2 Complete

IV. Change Areas of Interest

1. Wait for IntegrateCombineDetect script to be run for each tile
   a) Look for Detect_Lrn feature class in geodatabase
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\Detect_Lrn
2. Start editing Change_AOI
   a) Draw rectangles around areas of change between the 2006/2007 imagery and the 2013/2014/2015 imagery
   b) Use Detect_Lrn layer as guide
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\Detect_Lrn
   c) Save as Change_AOI in geodatabase
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\Change_AOI

Mark Tiles field 'Change_AOI Complete' "Yes"
'PHASE' = 3 Complete

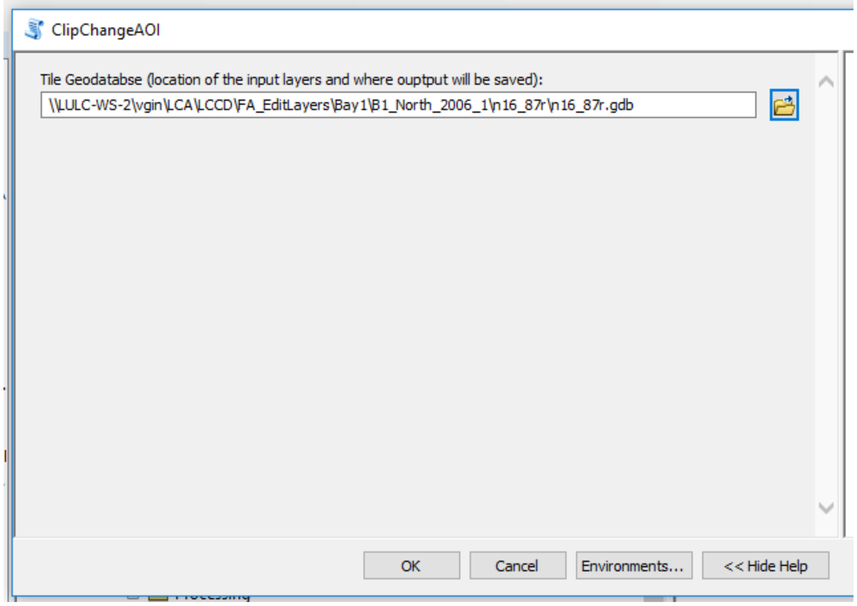
V. Clip Forest and Ag to Change AOIs

1. Look for ForestAg and Change_AOI in each geodatabase
\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\Change_AOI
2. Run ClipChangeAOI script

\\lulc-ws-2\vgin\LCA\LCCD\scripts\LCCD.pyt\ClipChangeAOI

a) Clips ForestAg layer to Change_AOI
b) Dissolves clipped ForestAg layer into single part features
c) Saves as ForestAg_edit

\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\ForestAg_edit



<u>VI. Forest & Ag Clean-Up</u>

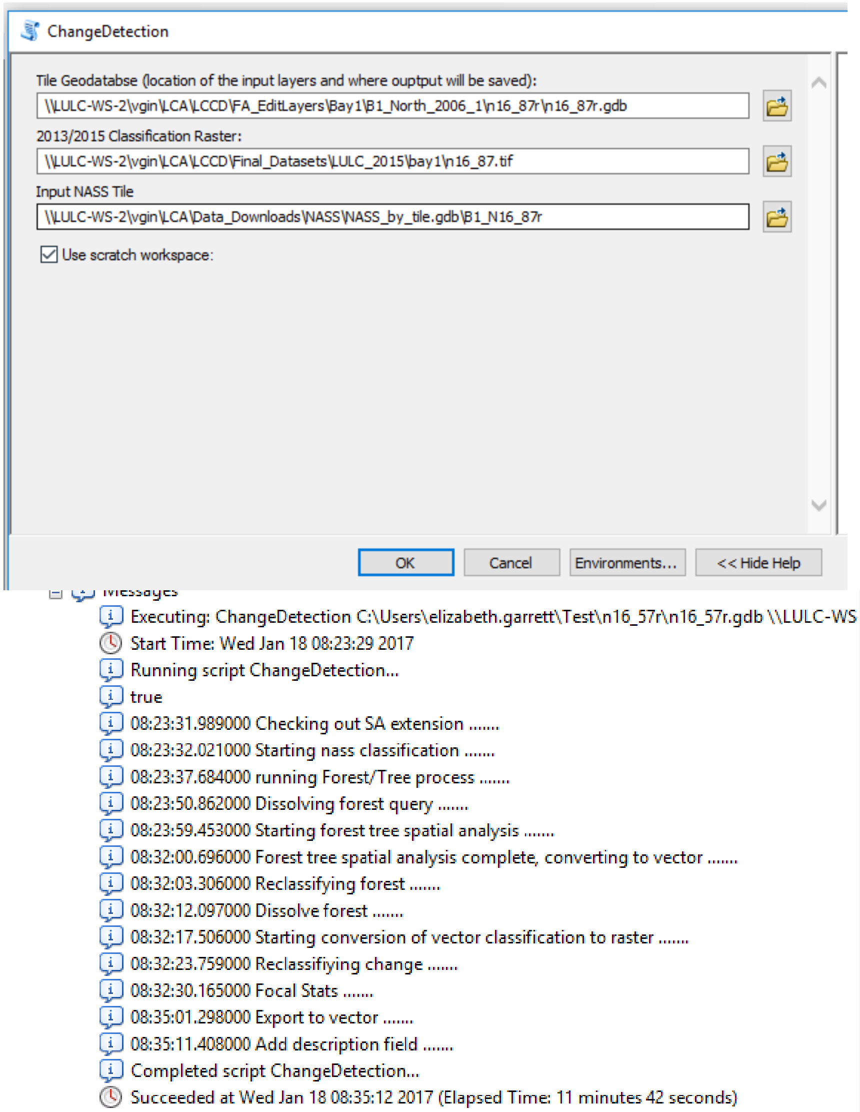
1. <u>Create local copy and edit features</u>
   a. Export ForestAg_edit from LULC-WS-2 to local copy
      \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\ForestAg
   b. Start editing ForestAg_edit
      i. Fill in (delete vertices) holes in forest where they shouldn't be
      ii. Delete/cut extraneous pieces of forest where they fall into other classes (scale 1:1500)
      iii. Add/remove/edit Ag features
      iv. Look at VDOF Forest Cover & NASS_Ag layers
          \\LULC-WS-2\vgin\LCA\Data_Downloads\VDOF\Forest Cover\vfcm05_level1
          \\LULC-WS-2\vgin\LCA\Data_Downloads\NASS\NASS_by_tile.gdb
      v. Use the later imagery to see if there was a change in the change AOI. If there was not a change, delete the forest and ag features within the AOI.
          See MaintenanceGuide on OneDrive
      vi. Save as ForestAg_FINAL in geodatabase

\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\ForestAg_FINAL

Mark Tiles field 'QC_Combine' "Yes"
'PHASE' = 4 Complete

VII. Change Detection

1) Run ChangeDetect script
\\lulc-ws-2\vgin\LCA\LCCD\scripts\LCCD.pyt\ChangeDetection
   a) Looks for tiled NASS features and overlays NASS Features with ForestAg_FINAL
      i) Only looks at NASS Pasture features
      ii) Calculates percent coverage
      iii) Reclassifies Crop (82) to Pasture (81) if feature is 75% covered or more
   b) Saves as 'ForestAg_FINAL_NASS' in gdb
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\ForestAg_FINAL_NASS
   c) Runs overlay of 2015/2013 LULC raster with a raster export of ForestAg_FINAL_nass
      i) Runs focal statistics on final raster to remove misclassified sliver features of change due to different angles and seasons of imagery
   d) Runs Forest/Tree Algorithm
   Uses Raster Calculations to develop 1 acre forested areas
      i. Select Class ID 40, 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
   e) Add new field with combined values for *BEFORE* (2006/2007) classification and *AFTER* (2013/2015) classification
   f) Marks all changes to developed (21, 22, 31, and 71) to turf (71)
   g) Adds final Description field that pulls values from external table
   h) Saves as *Tile_edit* in gdb
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\s23_38_edit



Mark Tiles field ‘NassReclass’ “Yes”
‘PHASE’ = 5 Complete
Mark Tiles field ‘ChangeDetect’ “Yes”
‘PHASE’ = 6 Complete

VIII. Final QC Run Through

1. Wait for Change Detect to be run for each tile
   a) Look for tile in geodatabase

\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\s23_38_edit

2. Bring in VBMP imagery service for both before and after years for the area you are working in
3. Start editing
   a) Heads up visual check of Tile changes for overall accuracy
      i) Deleting areas where there is no change
      ii) Adding new areas where change is visible
         (1) Digitize new features as needed using grid-code (the first two digits are the LCCD classification and the last two digits are the LULC classification)
         (2) Update ClassID with correct classifications (based on what you see in the imagery as the before and after classifications)

(3) Add change to developed as 8171, 8271, or 4071

iii) Reshape areas of change created in the last script to ensure accuracy

b) Update 2006/2007 class IDs for Ag

(1) Look at NAIP and NASS Ag to ensure that the correct “81__” and “82__” Ids are listed as input for the 4-digit change ID

c) Save as *Tile name*_FINAL in gdb

\\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\s23_38_FINAL

Mark Tiles field ‘Final_QC_Change’ “Yes”

‘PHASE’ = 7 Complete

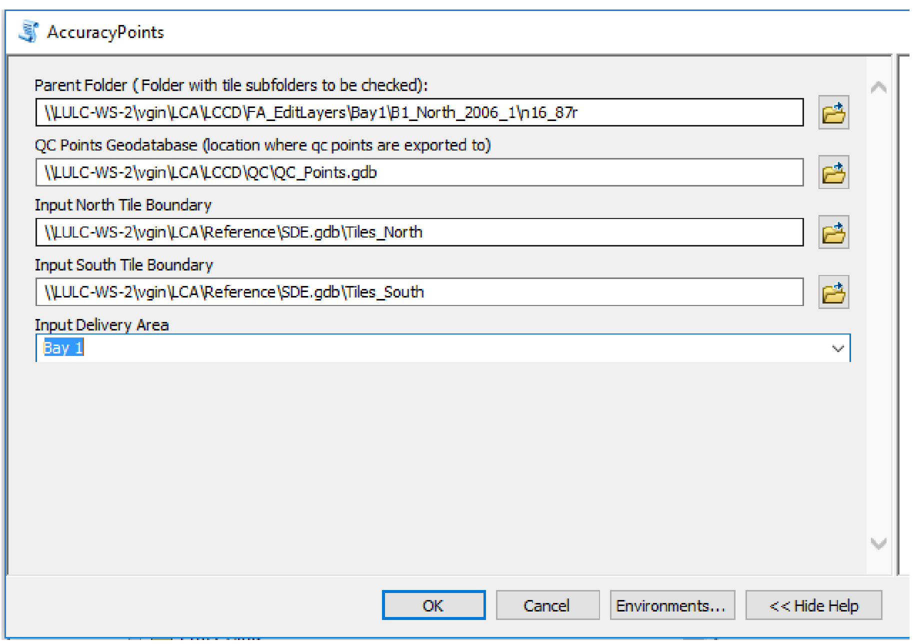
<u>IX. Final Tasks (per tile)</u>

1. <u>Accuracy Check</u>

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

a. Run script to develop accuracy points on completed tiles using “Create Random Points” geoprocessing tool
\\lulc-ws-2\vgin\LCA\LCCD\scripts\LCCD.pyt\AccuracyPoints

i. Develops random set of 25 point features (50 meter min. distance between points) per classification change category within each tile



b. <u>Accuracy check performed</u>

i. Add point features to map
\\lulc-ws-2\vgin\LCA\LCCD\QC\QC_Points.gdb\B1_s23_38

ii. Technician will compare points to VBMP imagery and mark fields appropriately

1. Mark 1 if the aerials match the grid-code and mark 0 if aerials do not match grid-code under the “Match” field

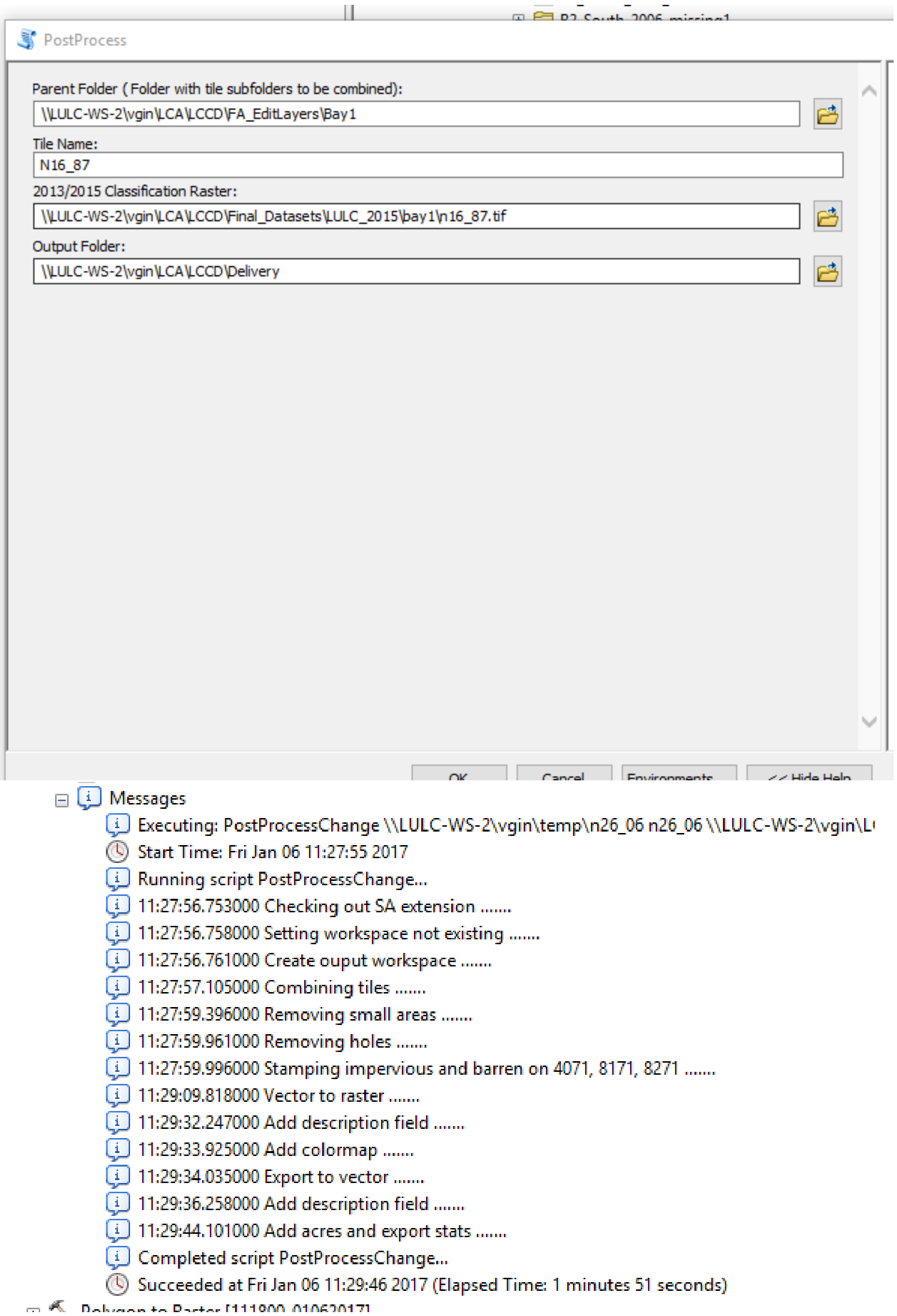
2. If the grid-code is correct, leave the “correct grid-code” field as null. If the grid-code is incorrect, fill in the correct grid-code in the “correct grid-code” field. A grid-code value of 0 means no change in this field.

Mark Tiles field ‘Accuracy_complete’ “Yes”
‘PHASE’ = 8 Complete

2. Tile Revisions
After Accuracy checks have been completed, tile will be QC'ed one last time to make necessary changes
   a) Bring in *“tile*_FINAL*”* feature class for the tile you are working on
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\s23_38_FINAL
   b) Bring in accuracy points to see if there were any unmatched areas
   \\LULC-WS-2\vgin\LCA\scripts\QC\QC_Points.gdb\s23_38
   c) Do a final run-through of the tile against the 2 years of imagery and make any final edits
   d) Look at surrounding tiles to match changes around the edges
   e) Save as *Tile name* in gdb
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\s23_38
   Mark Tiles field ‘Revisions_complete’ “Yes”
   ‘PHASE’ = 9 Complete

X.Post Processing (per tile)

1) Wait for final revisions to be completed
   a) Look for “*tile*” feature class in geodatabase
   \\LULC-WS-2\vgin\LCA\FA_EditLayers\Bay1\B1_2013_South_1\s23_38\s23_38.gdb\s23_38
2) Run PostProcess script
   \\lulc-ws-2\vgin\LCA\LCCD\scripts\LCCD.pyt\PostProcess
   a. If the tile was split into parts, the tool will search for all parts of tile (i.e. s23_05 & s23_05m)
   b. Creates raster & vector outputs by dissolving features with the same class adjacent to each other and removing areas of change less than an acre
   c. Removes holes less than 52 square feet from final output
   d. Stamps impervious and barren data from LULC onto turf change features
   e. Exports county tabular data
   f. Adds color-map of final symbology to Raster



Mark Tiles field ‘PostProcess’ “Yes”
‘PHASE’ = 10 Complete

Final Classifications

4011 – Forest to hydro
4021, 4022, 4031, 4071 – Forest to developed
4081, 4082, Forest to agriculture
8111, 8211 – Agriculture to hydro
8121, 8122, 8131, 8171, 8221, 8222, 8231, 8271 – Agriculture to developed
8141, 8151, 8161, 8191, 8241, 8251, 8261, 8291 – Agriculture to forest

SPATIAL ANALYSIS

I. Preliminary Tasks

1. Data Acquisition
   a. LULC vector data
      \\lulc-ws-2\vgin\LCA\LCSA\Final_LULC_Datasets\Vector\Bay_1.gdb
   b. Hydro feature class
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\CORR.gdb\Hydro
      i. From the following steps, create a statewide Hydro dataset of LULC vector hydro (CLASS_ID = 11) and LULC hydro overlay data
      ii. For each LULC raster tile, convert to vector with simplification enabled and extract CLASS_ID 11 from the vector data
      iii. Merge all converted LULC vector hydro data and all hydro overlay data into a single feature class
      iv. Buffer all tiles by 300 feet and intersect hydro with buffered tiles so as to create continuity between tiles during CORR analysis
      v. Dissolve into single part features and filter for hydro features > 0.1 acres
   c. CORR Buffer feature class
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\CORR.gdb\CORR
      i. With the hydro feature class run a multiple ring buffer at 35, 50, 100, and 150 foot distances on each tile
      ii. Assign the buffer distances to a “Buffer_Width” field
      iii. Convert multipart to single part features
      iv. Merge all tiles into a single feature class
   d. VBMP Tile Grid
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\Tiles.gdb\Full_tiles
   e. RCL Buffer data
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\RCL\LCSA_RCL.gdb\RCL_Buffer
      i. Buffer RCL data from LULC Land Cover dataset by an additional 15 feet
   f. DEMs - Statewide USGS 10m elevation raster
      \\lulc-ws-2\vgin\LCA\LCSA\Data_Downloads\USGS\vanclam_slope.tif
      i. Run spatial analyst Slope tool to calculate slope in degrees

II. Toolbox Setup

1. Inputs
   a. Delivery area geodatabase containing LULC vector tiles
      \\lulc-ws-2\vgin\LCA\LCSA\Final_LULC_Datasets\Vector\Bay_1.gdb
   b. Statewide hydrography feature class
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\CORR.gdb\Hydro
   c. Statewide buffered CORR feature class
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\CORR.gdb\CORR
   d. Statewide buffered RCL feature class
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\RCL\LCSA_RCL.gdb\RCL_Buffer
   e. Slope raster from elevation dataset
      \\lulc-ws-2\vgin\LCA\LCSA\Data_Downloads\USGS\vanclam_slope.tif
   f. Tile boundary feature class
      \\lulc-ws-2\vgin\LCA\LCSA\Reference\Tiles.gdb\Full_tiles

g. Input delivery area
Bay Area 1
h. Directory to export to scratch and export features by tile
\\lulc-ws-2\vgin\LCA\LCSA\Pilot\deliverable\Deliverable_pilot

2. Scratch features
   a. 'corr_components.gdb*tile*_lulc': LULC vector tile reclassified into Developed, Natural, Pasture, and Crop
   b. 'corr_components.gdb*tile*_segments': CORR buffer broken into 5 foot segments
   c. 'corr_components.gdb*tile*_segements_lulc': LULC intersected with segments identifying classes in each thiessen feature
   d. 'corr_components.gdb*tile*_segments_classified': Primary class added to each thiessen feature within each buffer zone
   e. 'corr_components.gdb*tile*_impervious_zones: Impervious features within CORR buffer assigned values for % impervious in Developed Network, Developed Network Size, Hydro Proximity, and Slope
   f. 'corr_components.gdb*tile*_urban': Impervious features and pervious features that intersect impervious features
   g. 'corr_components.gdb*tile*_urban_network': Developed features buffered by 75 feet and dissolved to create a continuous network of developed features
   h. 'corr_components.gdb*tile*_urban_network_classify': Developed Networks classified by sum of impervious, sum of pervious, developed size, and % impervious

3. Export features
   a. 'corr_deliverable.gdb*tile*': Dissolved corridor buffer zones of primary class in each thiessen feature
   b. 'impervious_deliverable.gdb*tile*': Impervious features within corridor characterized according to slope, hydro proximity, developed network size, and % impervious in developed network

III. Corridor Extraction

1. Reclassify LULC data
   a. Reclassify 31 – Barren and 22 – Impervious (local) into 21 – Impervious to create Developed class
   b. Reclassify 42 – Tree, 51 – Scrubshrub, 61 – Harvested, and 91 – Wetlands into 41 to create Natural class
   c. Iterate through class 71 – Turf and assign to the following:
      i. If intersects Developed, assign as Developed
      ii. If intersects Pasture or Crop and not Developed assign as Pasture or Crop
      iii. If any Turf remaining, assign as Natural
   d. Export 'corr_components.gdb*tile*_lulc'
2. Create thiessen polygons
   a. Buffer input Hydro feature class by 305 feet so that the thiessen polygon analysis will create a continuous feature across the width of the 150 ft corridor
   b. Densify the 305 ft buffer by 5 feet so that thiessen polygons will be 5 feet in width along the corr corridor
   c. Execute the following on each buffer of the CORR Buffer feature class to prevent the Thiessen polygons analysis tool from failing with too much data:
      i. Convert the CORR buffer to points

ii. Run thiessen polygons on the points
iii. Clip the thiessen polygons to the corr corridor
d. With the thiessen polygons, add a field Segment_Key to uniquely identify a 5 feet wide segment of thiessen polygons in each buffer zone
e. Union the thiessen polygons with the corr buffer to break the thiessen polygons into the buffer zones
f. Export 'corr_components.gdb*tile*_segments'

3. <u>Integrate LULC datasets</u>
a. Add fields "Class_List" and "Primary_Class" to 'corr_components.gdb*tile*_segments'
i. Class_List = All classes within each thiessen feature
ii. Primary_Class = Predominate class within each feature
b. Add all CLASS_ID of all LULC features within each thiessen feature and identify the primary class if only one class in the feature. Geoprocessing tools are not used in this step for performance constraints due to the size of the thiessen polygon outputs.
i. Iterate through each class (Developed, Natural, Pasture, Crop) in 'corr_components.gdb*tile*_lulc'
ii. Add the CLASS_ID of each feature to the Class_List field of each thiessen feature that the class intersects
iii. If the thiessen feature has only one CLASS_ID in the Class_List, add the class to Primary_Class
c. Export 'corr_components.gdb*tile*_segements_lulc'

4. <u>Identify Primary Class</u>
a. Take all the thiessen features with multiple classes in Class_List and intersect with 'corr_components.gdb*tile*_lulc'
b. For performance, use ArcPy's numpy library to find the CLASS_ID with the max area within each thiessen feature
c. Update Primary_Class with the CLASS_ID with the max area
d. Export 'corr_components.gdb*tile*_segements_classified'

5. <u>Classification Cleanup</u>
a. Remove any features that failed with a null Primary_Class caused by thiessen polygons creating sliver features within hydro
b. Dissolve 'corr_components.gdb*tile*_segements_classified' by Buffer_Width and Primary_Class to create continuous classes of Developed, Natural, Pasture, and Crop within each buffer zone
c. Recursively iterate through each feature < 0.01 acres in each zone and assign the Primary_Class of the neighboring polygon feature > 0.01 acres using the Polygon Neighbors gp tool
d. Export 'corr_deliverable.gdb*tile*_corr_classified'

<u>IV. Impervious Analysis</u>

1. <u>Create Developed Network</u>
a. From LULC Vector Tile:
i. Extract CLASS_ID 21 and 22 and classify as impervious
ii. Extract CLASS_ID 71 where it intersects impervious and classify as pervious features
iii. Export 'corr_components.gdb*tile*_<u>urban</u>'
b. Create developed network
i. Erase 'corr_components.gdb*tile*_urban' by RCL buffer

ii. Dissolve erased features into single_part and filter out any sliver pieces < 0.01 acres
iii. Buffer remaining features by 75 feet and clip to tile boundary
iv. Export 'corr_components.gbb*tile*_urban_network'

2. Identify Impervious within CORR
   a. Extract impervious features from 'corr_components.gdb*tile*_urban' and dissolve into single_part to preserve connectivity of impervious features within CORR boundary
   b. Clip impervious to CORR boundary
   c. Add fields:
      i. Developed_Size – SHORT
      ii. Perc_Imperv – SHORT
      iii. Hydro_Proximity – SHORT
      iv. Slope – SHORT
   d. Export 'corr_components.gdb*tile*_impervious_zones'
3. Calculate Impervious Proximity to Hydro
   a. Run a near analysis between 'corr_components.gdb*tile*_impervious_zones' and hydro to find the distance between
      i. Add field NEAR_DIST to identify distance and location of nearest point on hydro
   b. Attribute field Hydro_Proximity
4. Calculate Slope of Impervious Feature
   a. With 'corr_components.gdb*tile*_impervious_zones', add a field JOIN_OID (type FLOAT) and calculate the field value to the OBJECTID field
   b. Extract all the centroids from impervious features as a point feature class with OID added to JOIN_OID field
      i. For multipart features, extract the centroid of each feature within the multipart feature
   c. Run the gp tool ExtractValuesToPoints with the elevation raster as an input to find the elevation of each point
   d. For each impervious feature, find the matching point or points via the JOIN_OID field and extract the average slope value rounded to the nearest whole number from the field RASTERVALU created by ExtractValuesToPoints
   e. Attribute field "Slope"
5. Calculate Size and % Impervious of Developed Network
   a. For each feature in 'corr_components.gdb*tile*_urban_network', sum the total impervious and pervious features in the fields Acres_Impervious and Acres_Pervious
   b. For each impervious feature in 'corr_components.gdb*tile*_impervious_zones', find all developed network features the impervious feature intersects (feature such as road features may be in multiple networks)
   c. Assign to field Developed_Size the sum of Acres_Impervious and Acres_Pervious from all network features
      Assign to field Perc_Imperv the result of Acres_Impervious divided by Developed_Size
   d. Assign Developed_Size from the network feature to the impervious feature
   e. Assign Perc_Imperv from the network feature to the impervious feature
6. Export Final Impervious Features
   a. Export 'corr_components.gdb*tile*_impervious'

V. Final Tasks (per tile)

1. Accuracy check

VI. Post Processing (per tile)

1. Wait for final revisions
2. Run PostProcess script