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Managing Water in the West

Minute 319 Pulse Flow

Riparian Vegetation Mapping

Lower Colorado River

Morelos Dam, U.S. to Gulf of CA, Mexico

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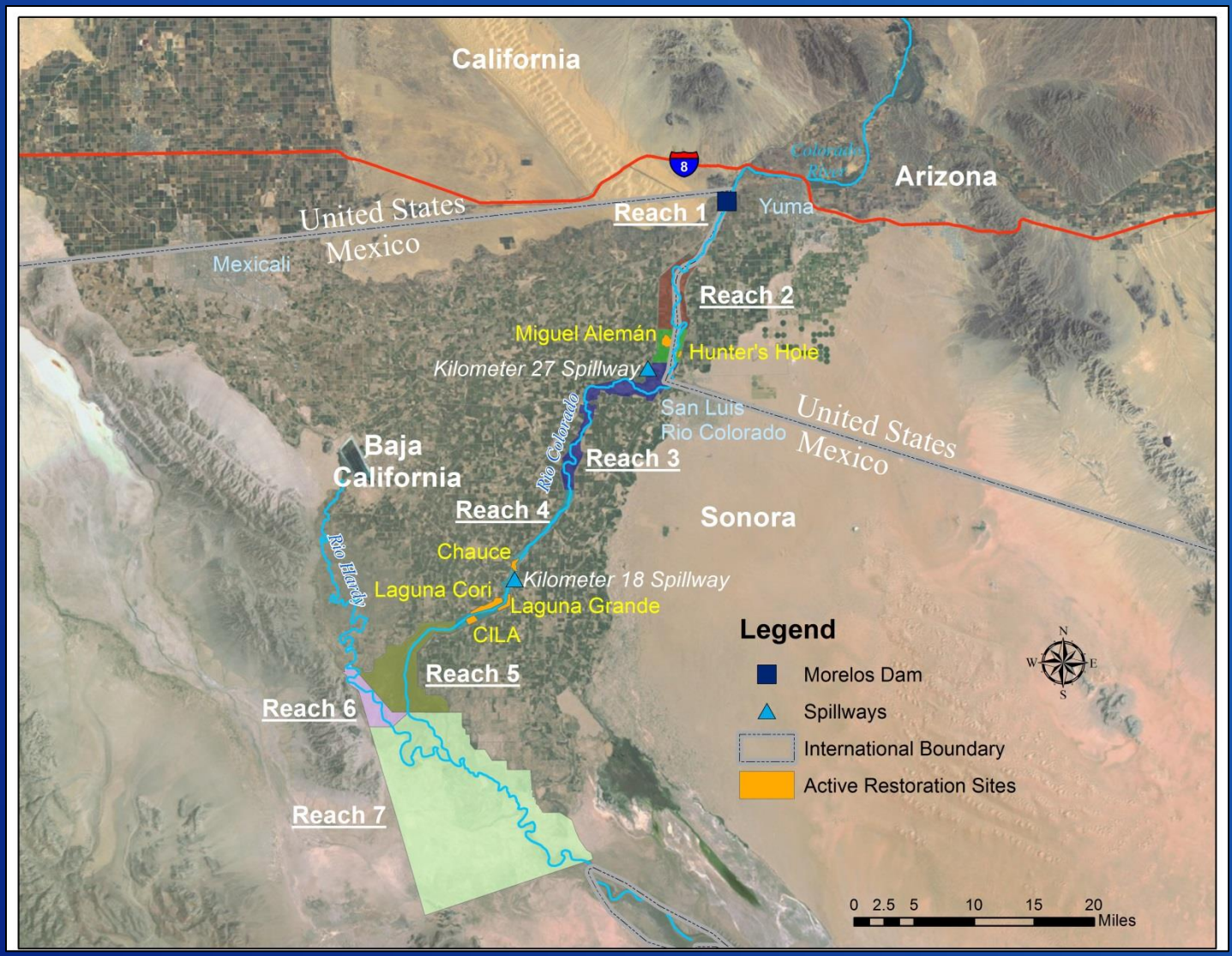
U.S. Department of the Interior
Bureau of Reclamation

Minute 319 Overview

- Minute 319 (signed in 2012) is a minute to the 1944 Treaty with Mexico and represents a historic binational agreement to guide future management of the Colorado River through 2017.
- One of many actions in the minute provides water for environmental flows for the Colorado River Delta.
- The March 2014 Pulse Flow release from Morelos Dam was the first event to provide this water. Approximately 195,000,000 cubic meters was released starting March 23 and continuing through May 21, 2014.
- Binational science teams planned the many aspects of the flow release and are currently conducting multiple scale monitoring and modeling studies to gain important scientific information on the effectiveness of the flow.
- A principal goal is to provide water for both passive and active riparian restoration sites to aid in restoring native riparian habitat.

- http://www.usbr.gov/lc/region/feature/minute319.html

Minute 319 Pulse Flow Project Area



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1 Mile North of Southern International Border

March 20, 2014

March 27, 2014

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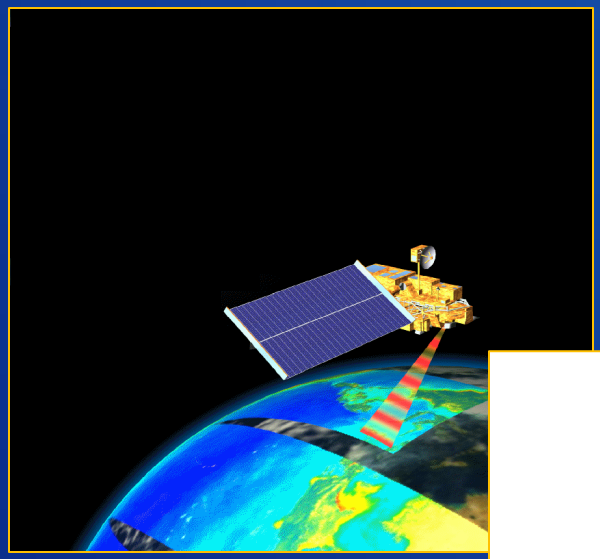
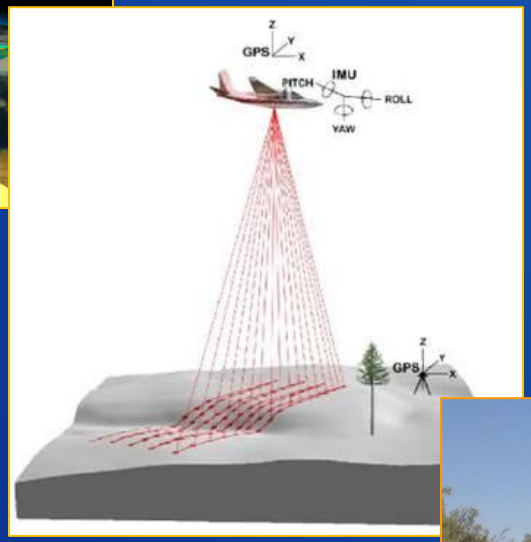
Minute 319 Remote Sensing – General Activities



Spectral Data Acquisition: Varying Scales and Frequency

- MODIS Satellite: 250 meter, 2 day repeat
- Landsat Satellite: 15-30 meter, 8 day repeat
- ASTER Satellite: 15-30 meter, task by request
- World View 2 Satellite: 2 meter, task by request
- Digital Aerial: 6 inch – 1 meter, task by request



LiDAR Data Acquisition

- Pre and Post Pulse acquisition
- Digital Elevation Model:
  - 1 meter horizontal posting
  - 10 cm vertical accuracy
- Classified Point Cloud Data
  - Vegetation Height
  - Bare Earth

These data are combined with field data for scientific studies to understand and monitor the effects of the pulse flow

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Project – wide Pre-pulse Vegetation Mapping

Purpose: Create project scale pre-pulse vegetation map to categorize baseline conditions for future monitoring

Primary Data

- LiDAR pre pulse DEM
- LiDAR pre pulse point cloud data
- WV2 , 2 meter multispectral (ms) and 0.5 meter panchromatic (pan) satellite imagery
- 6 inch true color digital aerial imagery (moderately rectified)
- Various vegetation field data sets from Pronatura and Sonoran Institute (Mexico Non Profits), and University of AZ.
- Additional field work as necessary

Primary Attributes

- Vegetation height and crown closure
- Land cover / Vegetation type

Methodology

- Object Based Image Analysis

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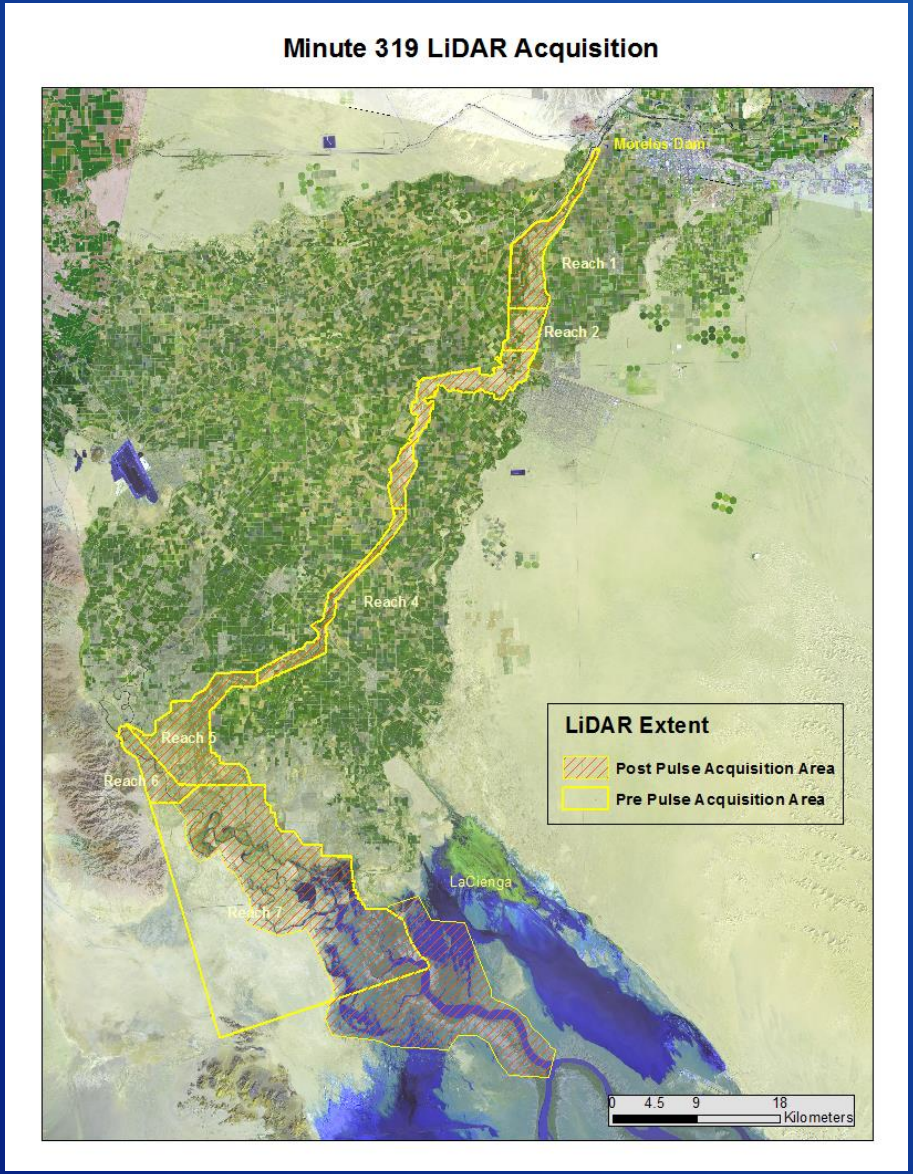

LiDAR Acquisition

Contracted through USGS National Geospatial Technical Operations Center

Pre Pulse Flow LiDAR: ~ 1350 sq. km

- March 7-20, 2014
- Average LiDAR point densities
  - First-Return: 10.67 pts/m2
  - Ground Classified: 5.77 pts/m2

Post Pulse LiDAR: ~ 700 sq. km

- Mid to Late July, 2014 Acquisition
- Acquisition area modified in Reach 7 to provide enhanced baseline data for erosional and depositional studies in the intertidal zone
- Currently being processed by contractor

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LiDAR LAS File Contractor Specifications

Classification Number	Classification Name	Classification Description
2	Ground	Bare earth ground, determined by a number of automated and manual clean algorithms
3	Low Vegetation	Any vegetation within 1.5 m of the ground surface
4	Medium Vegetation	Any vegetation between 1.5 and 4.6 m above ground
5	High Vegetation	Any vegetation greater than 4.6 m above ground
6	Building	All man-made structures such as buildings, bridges, fences and utilities
7	Noise	Laser returns that are often associated with birds, scattering surfaces, etc.
9	Water	Laser returns that are determined to be water using automated and manual cleaning algorithms
10	Ignored Ground	Ground points proximate to water's edge breaklines; ignored to correct model creation
11	Withheld	Laser returns that have intensity values of 0 or 255

World View 2 Imagery (WV2)

- WV2 multi-spectral / pan data collect requested through National Geospatial-Intelligence Agency - NGA / US Geological Survey Commercial Remote Sensing Space Policy (CRSSP, 2003).
- Imagery collected in Fall 2013 (pre-pulse flow)
- Unfortunately, a single collection date did not cover the entire project area.
- However, most individual river reaches were covered by a single image date.
- Imagery was mosaiced by reach to accommodate varying image collection dates and image classification and processing considerations.

Digital Globe WorldView 2
Launched Oct. 8, 2009

Spectral Bands

Spatial Res.
MS ~ 2m
Pan ~ 50cm

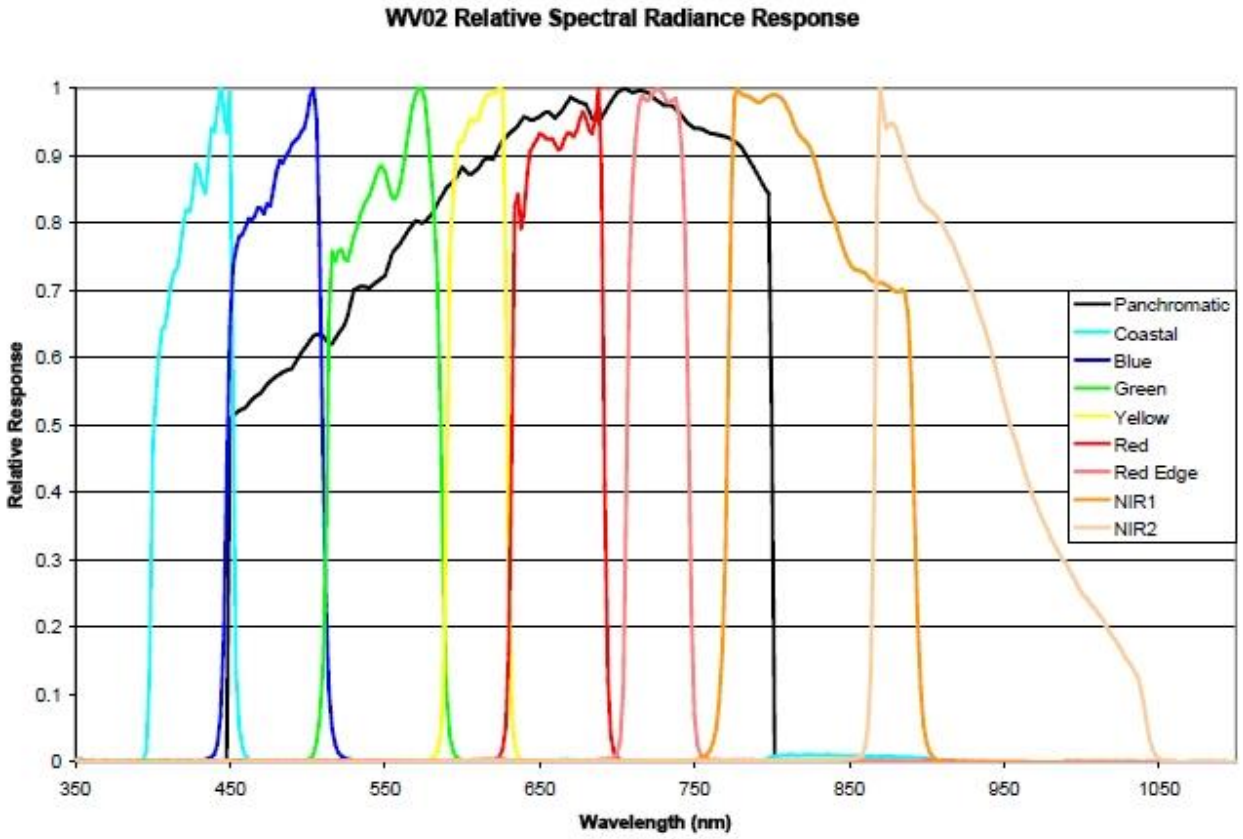

Figure 2. Spectral Response of the WorldView 2 panchromatic and multispectral imager.

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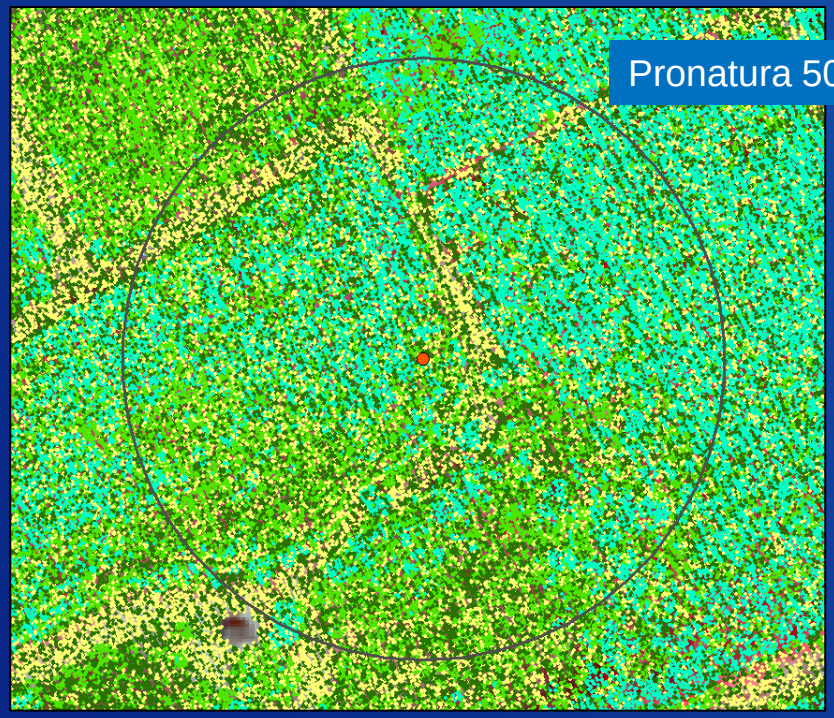
Database Building
General Processing Workflow
Testing and Demonstration Phase – Reach 4

- Create WV2 ms and pan mosaics by reach boundary from source image tiles (ERDAS Imagine)
- Create DEM mosaic for entire project area from source LiDAR-derived DEM tiles delivered by contractor (ERDAS Imagine)
- Create ArcMap LAS Dataset by reach (i.e. Reach 4)
- Create 1 meter raster Digital Surface Model (DSM) for Reach 4 (ArcMap)
- Create 1 meter raster Canopy Height Model (CHM) for Reach 4 (ArcMap)
- Register WV2 ms imagery to CHM. Control file based on WV2 pan imagery and CHM (ArcMap)

* Green text denotes further clarification in upcoming slides

Database Building: Create ArcMap LAS Dataset by Reach

- LiDAR .las files delivered in 1000m x 1000m tiles
- Based on .las index, select tiles covering Reach 4 and copy to Windows folder (LAS_Reach_4 : 130 tiles, 10.8 GB)
- In ArcCatalog: create new las dataset. Using “properties” for new las dataset, add LAS_Reach_4 folder and calculate statistics.



LAS dataset view of classified LAS points

WV2 ms imagery

Yellow = ground returns
Dark green to cyan = vegetation returns (increasing height)
Other returns filtered out in this view

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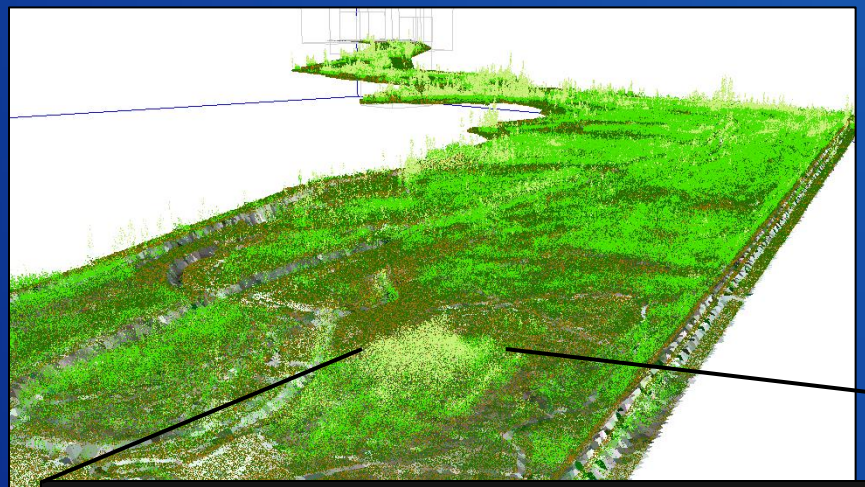
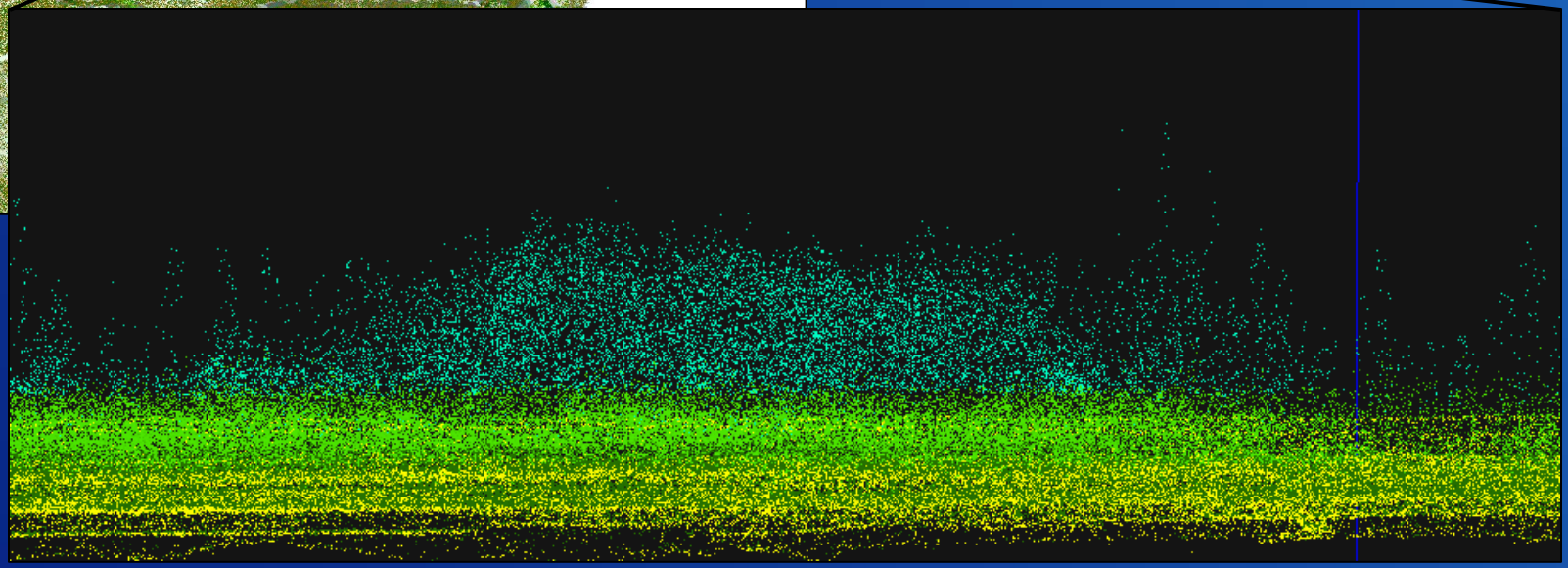
LAS Point Files – 2D & 3D Views



3D View Looking North from
CILA Restoration Area



Cross Section of LiDAR Points – CILA Restoration Area

Yellow = ground returns
Dark green to cyan = vegetation returns
Other returns filtered out in this view

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Database Building: Create 1 meter Digital Surface Model (DSM)

- **LAS Dataset to Raster tool (ArcMap) –** this tool is used to create a 1 meter DSM from the LiDAR las dataset. Before running the tool, use the properties dialogue for the las dataset to apply filters so that only desired points are used (i.e.. filter out 'noise', 'building', and 'reserved' classes – this may vary with the nature of the classified las point data specifications).

  - *** Parameters: Value Field: Maximum; Interpolation Method: binning; Cell Assignment Type: Maximum; Void Fill Method: linear; Sampling Type: CELLSIZE; Sampling Value: 1 (for 1 meter cell size). Important: under 'environments' in this dialogue, "processing extent", set snap raster to DEM file to assure output DSM raster cells properly align with DEM.**

- **Extract by Mask tool (ArcMap) –** this tool is used to mask the DSM from the above process to match the WV2 imagery reach mosaic for further processing.

  - **Parameters: Mask file: WV2 image for Reach 4. Under 'environments' in this dialogue, set cell size to 1 meter under Raster Analysis / Cell Size; set snap raster to DEM file (otherwise resampling will occur based on the WV2 mask file and cells will not align with the DEM).**

* Parameters recommended by Clayton Crawford, ESRI Lastools workshop, 2014

Database Building: Create 1 meter Canopy Height Model (CHM)

- **Minus tool (ArcMap) –** This tool subtracts the value of the second input raster from the value of the first input raster (First input raster – Second input raster).
  - **Parameters: First input raster: DSM file; Second input raster: DEM file. Under 'environments' in this dialogue, set the processing extent to the reach specific DSM file since the DEM is for the entire project area.**

CHM (1 meter raster)

WV2 imagery

Black to white = 0 to approximately 14 meters in height

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Database Building: Register WV2 ms imagery to CHM based on WV2 pan imagery and CHM for control (ArcMap)

- Typical orthorectified image products do not have as high a level of geometric control as that provided by LiDAR data. Imagery is registered to the CHM before proceeding with classification work.
- ArcMap georeferencing tools are used to create transformation control files based on tree centers; tying WV2 pan 0.5 imagery to the CHM. This control file is then used to transform the WV2 pan imagery, as well as WV2 ms imagery.
- 'Adjust' transformation in ArcMap is used, rather than a 3rd order polynomial, as this method uses a combination of polynomial and TIN interpolation to accommodate local variation, such as that seen in areas of very tall trees.

- Na Li, et. al. Registration of Aerial Imagery and Lidar Data in Desert Areas Using the Centroids of Bushes, PE&RS, August, 2013.

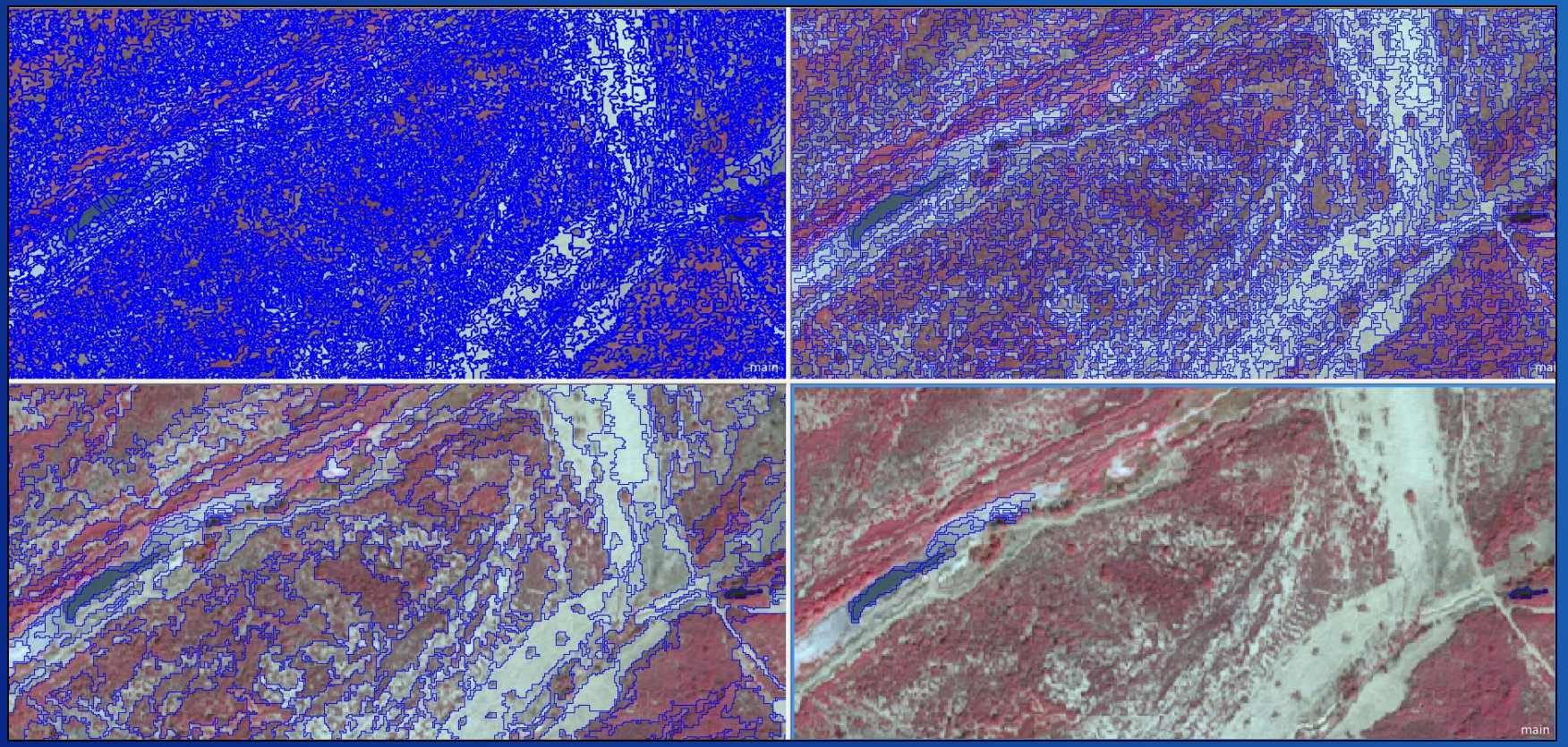
Vegetation Classification
Testing and Demonstration Phase – Reach 4

- Object Based Image Analysis (Ecognition)
- Input Data: CHM, WV2 ms imagery
- Multiple image object scales are created to address a variety of classification requirements:
  1. Vegetation Canopy Height
  2. Predominant Vegetation Type
  3. Anderson Ohmart Classification Structure and Vegetation Types
  4. Crown Closure
  5. General land cover ‘strata’ : Land, Water, Vegetated, Barren

Example: Four Object Scales

Small scale CHM objects (cleaned/merged) (1.2 million objects)

Medium Scale Vegetated/NotVegetated objects (169,000 objects)



Larger scale stand boundary objects for Anderson Ohmart and Crown Closure

Largest scale Land/Water objects

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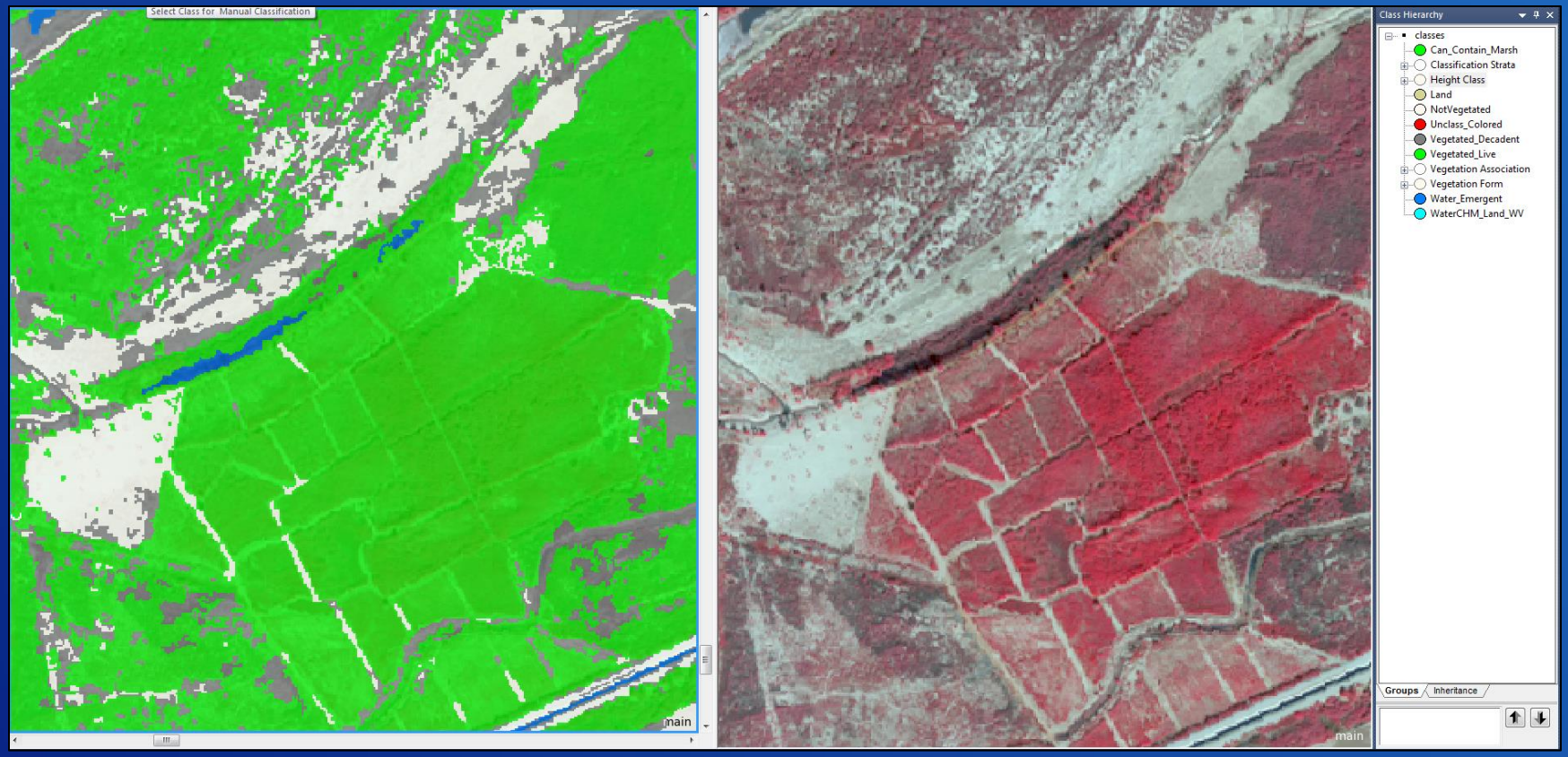
Vegetation Classification
General Processing Workflow

- Basic Workflow
  - Multiresolution segmentation for medium to larger scale objects (using WV2 ms imagery). These created for mapping general ‘strata’:
    - Vegetated & Vegetated Decadent, Not Vegetated, Water & Land
    - Assign general Land & Water, Vegetated & Vegetated Decadent, and NotVegetated classes to objects based on spectral thresholds (i.e. NDVI, band ratios, etc.)
  - Iterative Contrast Split Segmentation for small scale objects – using the LiDAR derived raster CHM and based on user-defined height breaks (WV2 ms not used). These created for canopy height classification:
    - Assign height classes to ‘contrast-split’ objects
    - Merge and ‘clean’ height class objects to simplify and omit unnecessary ‘pits’ (very small gaps in canopy where LiDAR penetrated to ground)

Object-based Vegetated, Vegetated Decadent, & Not Vegetated, Classification



Classification

World View 2 Imagery

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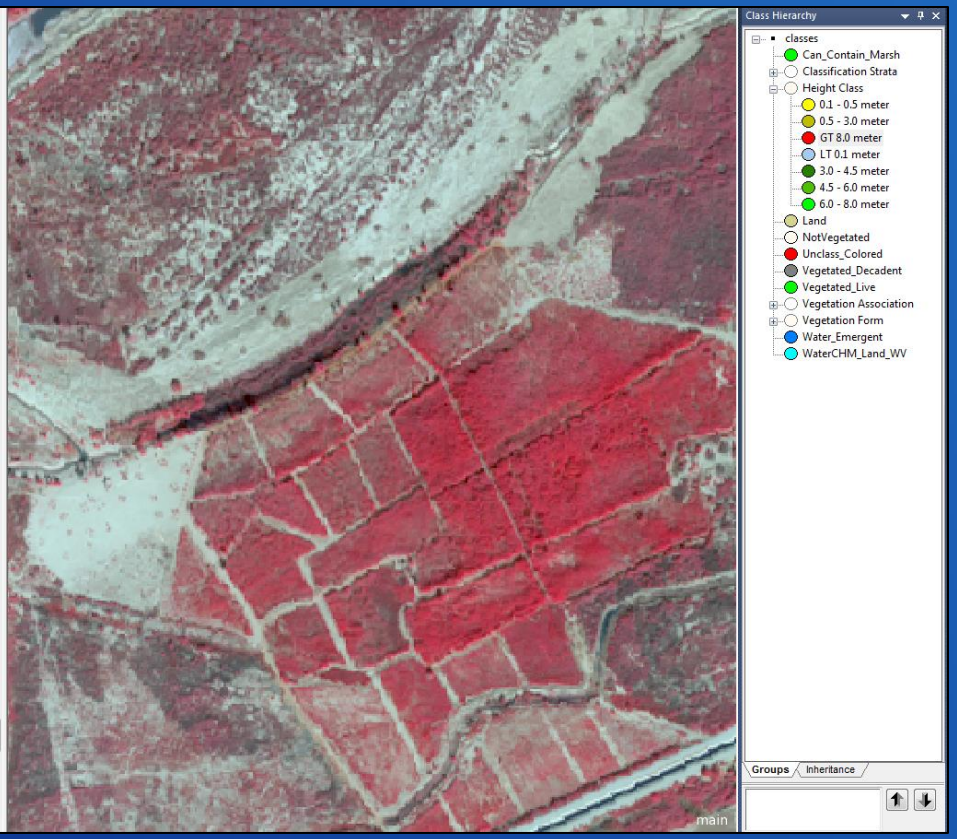
Object-based Canopy Height Classification



Canopy Height Classification

World View 2 Imagery

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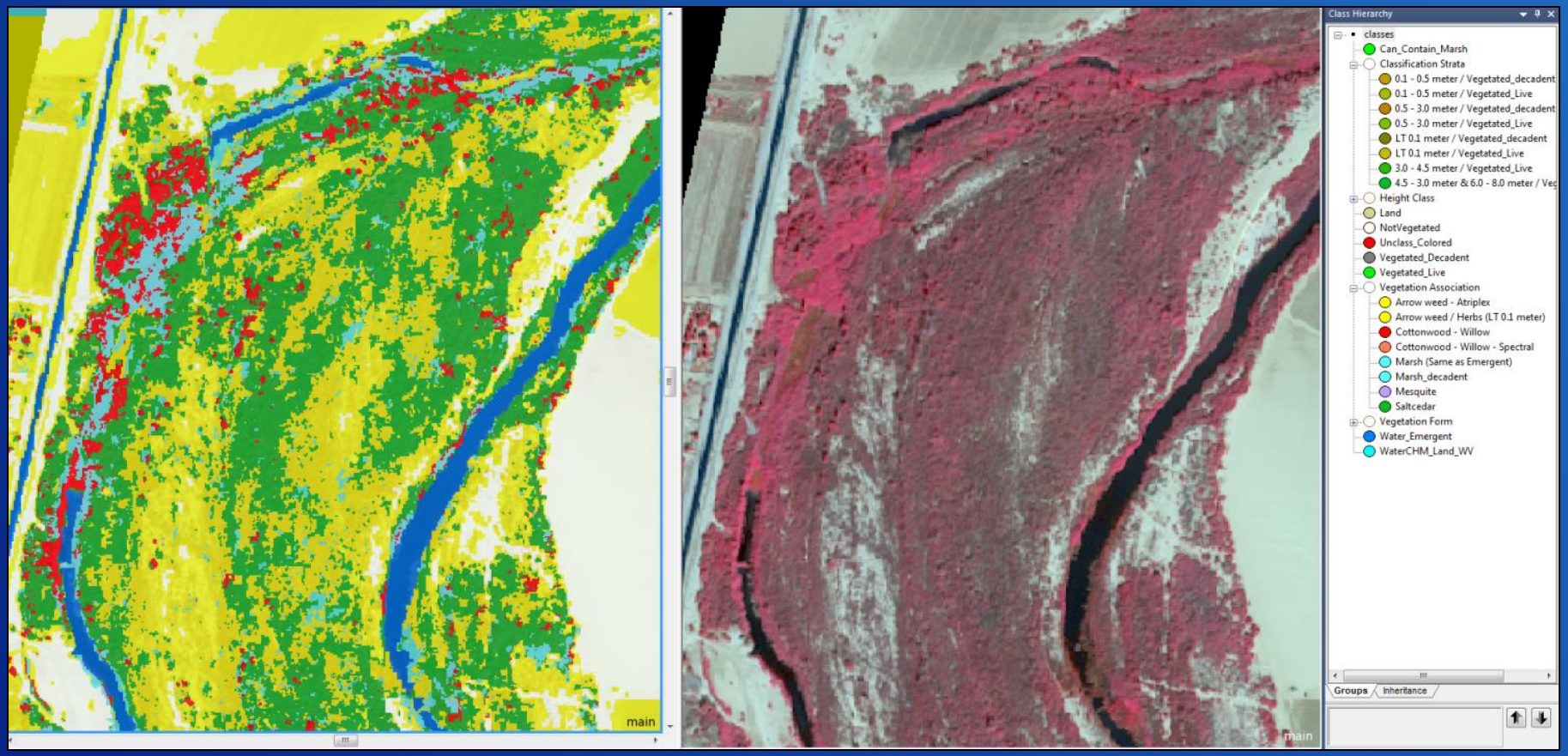
General Processing Workflow: Vegetation Classification - Continued

- Basic Workflow
  - Vegetation Type classification using fine scale CHM-objects
    - Separate classifications within each height strata (reduces spectral variability and class variability)
    - Many potential object-based classification approaches including spectral classifiers, decision tree classifiers, Boolean thresholds based on desired variables.
    - Many available variables including WV2 spectral bands and derived variables (i.e.. NDVI, band ratios, texture, etc.), CHM metrics
  - Multiresolution segmentation for vegetation stand-scale objects (using WV2 ms imagery and raster CHM, and 'built' from fine scale CHM-objects)
    - Appropriate scale for assigning crown closure classes & vegetation classes (based on specific classification system rules and the classification results at the finer scale), and structure classes based on finer-scale CHM-objects.

Object-based Vegetation Type Classification – Fine Scale



Minimum Distance Classifier

- Classified by height strata
- Variables used: WV2 multispectral bands and various band ratios

World View 2 Imagery

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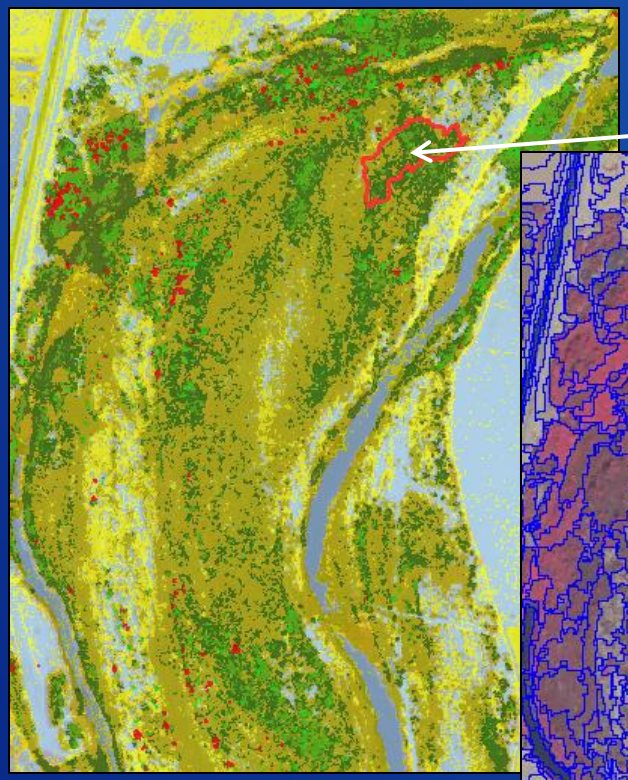
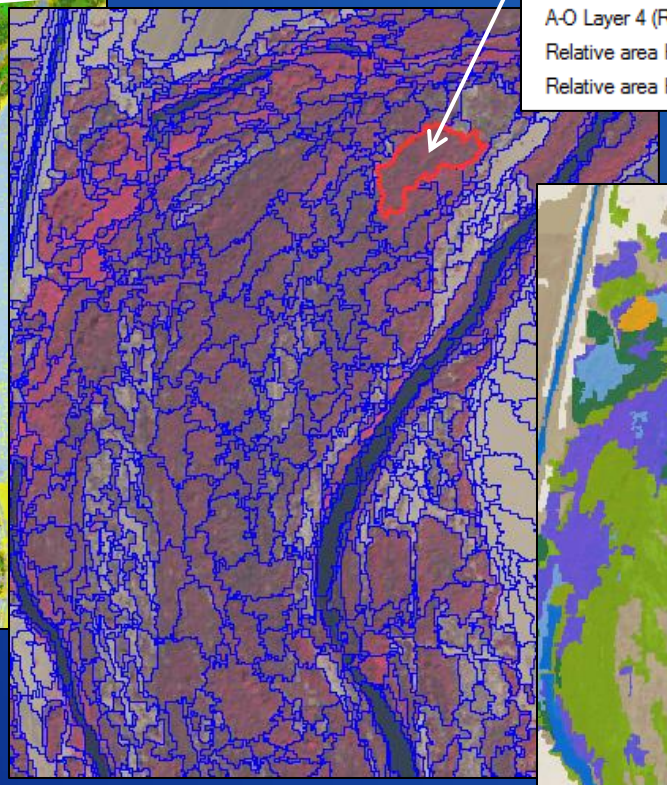
Anderson Ohmart Vegetation Structure Classification

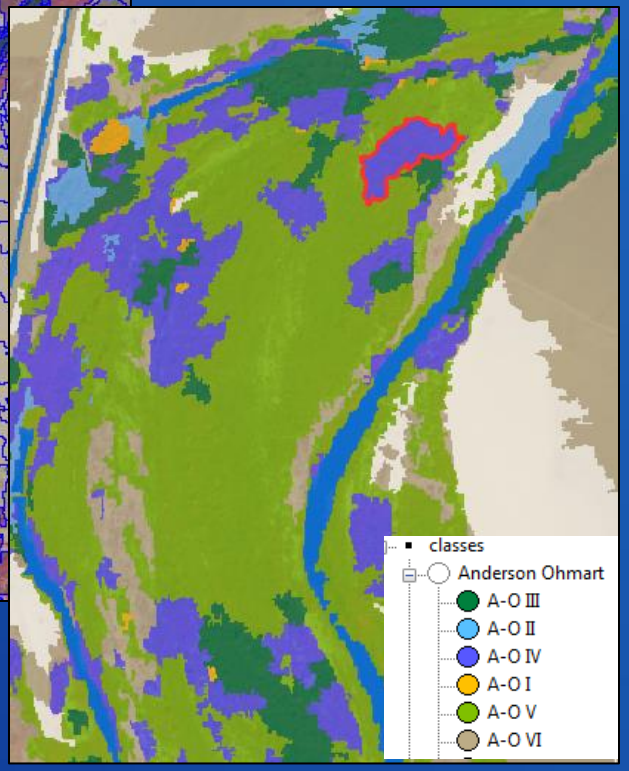


Canopy Height Classification
(small scale objects)

Class-Related features	Customized
A-O Layer 1 (Rel. area LE 0.5 meter)	0.011555
A-O Layer 2 (Rel. area GT 0.5 meter _LE 4.5 meter)	0.8783
A-O layer 3 (Rel area GT 4.5 meter _LE 8.0 meter)	0.1075
A-O Layer 4 (Rel. area GT 8.0 meter)	0.00264513
Relative area Height class GT .1	0.9937
Relative area Height class GT 3.0	0.6560



"Stand Boundary" Objects
(larger scale)



Vegetation Structure Classification based on "relative area of height class" rules

Classification rules for one object scale can be based on metrics from a different object scale

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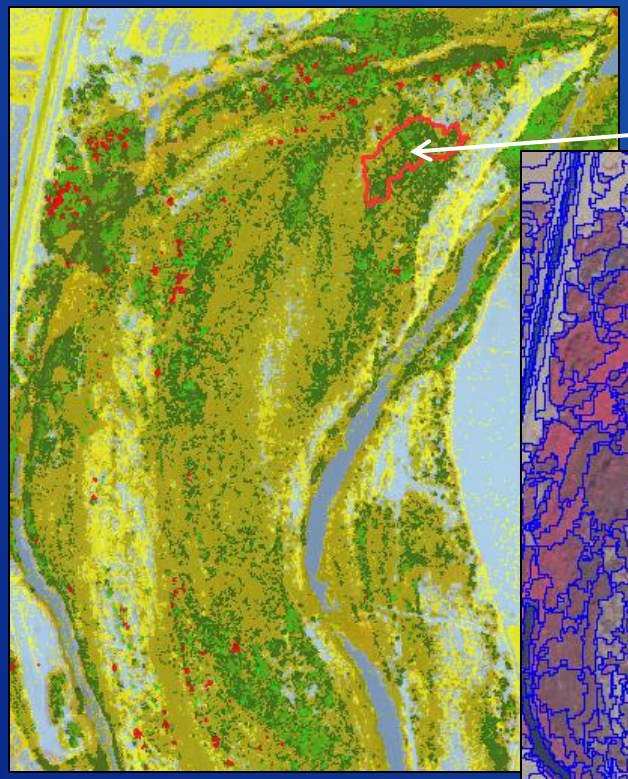
Anderson Ohmart Vegetation Canopy Cover Classification



Canopy Height Classification
(small scale objects)

Class-Related features	Customized
A-O Layer 1 (Rel. area LE 0.5 meter)	0.011555
A-O Layer 2 (Rel. area GT 0.5 meter _LE 4.5 meter)	0.8783
A-O layer 3 (Rel area GT 4.5 meter _LE 8.0 meter)	0.1075
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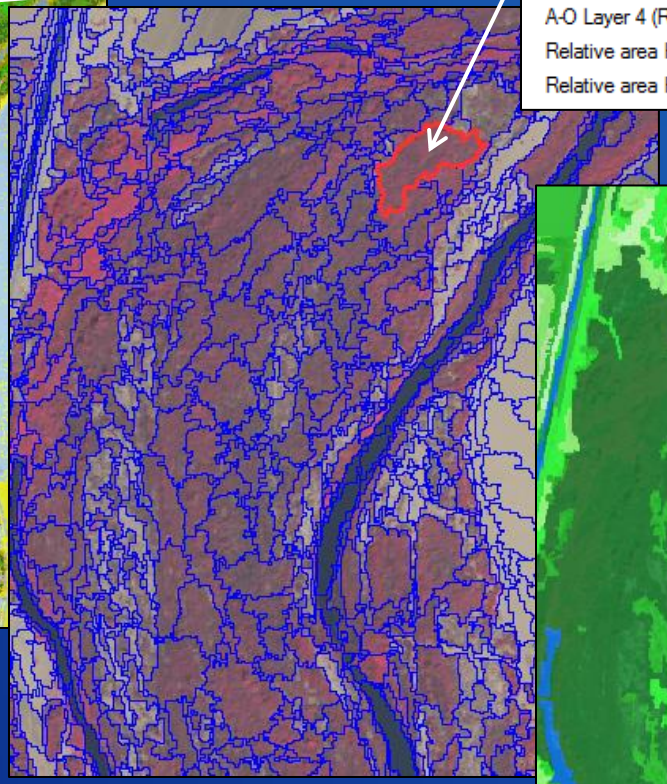
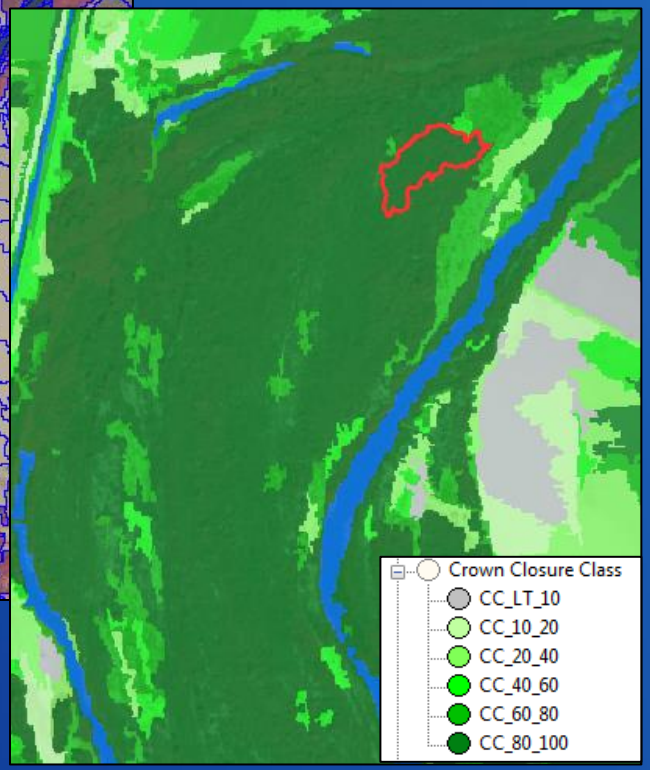


"Stand Boundary" Objects
(larger scale)



Vegetation Crown Closure Classification based on "relative area of height class GT 0.1 meters

Classification rules for one object scale can be based on metrics from a different object scale

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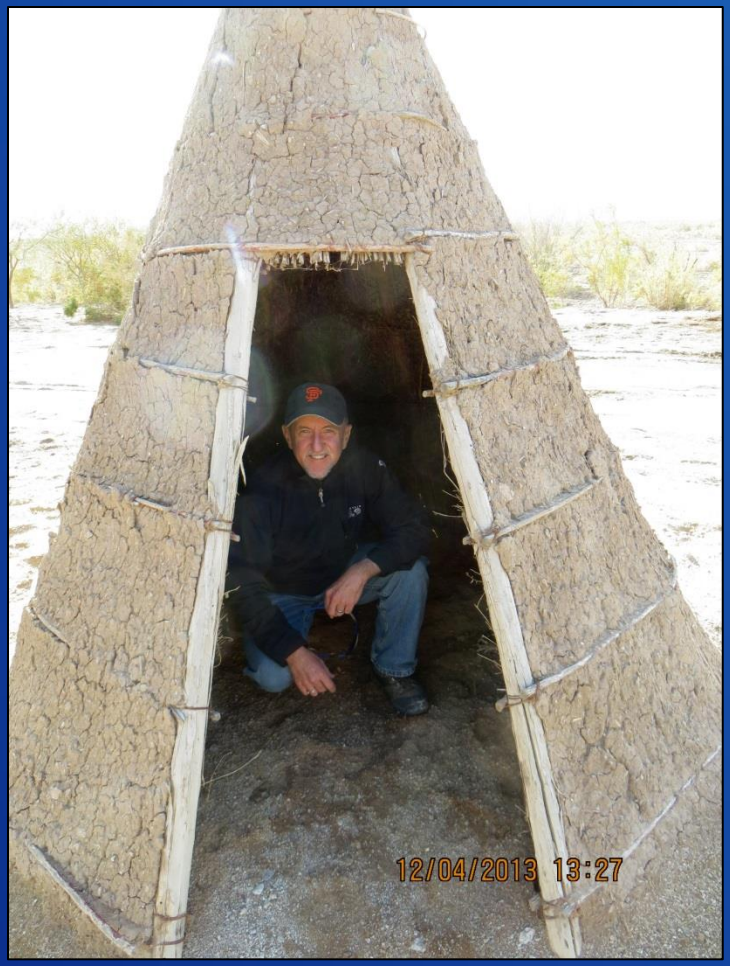
Thank You !



Jeff Milliken, Colorado River Delta, Mexico

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Additional Resources

- Video on contrast split segmentation for developing Object-Based CHM:

  Jarlath O'Neil-Dunne , Univ. of Vermont, Director Geospatial Analysis Center

  http://www.uvm.edu/~joneildu/Video/Definiens/TreeCanopy_LiDAR/TreeCanopy_LiDAR_controller.swf

- Ecognition video library on OBIA and LiDAR – examples
  - (search Ecognition tutorial in Google or go to Ecognition website)

- Sesnie, Steven, Mueller, J. et. al., Landscape-scale habitat characterization for the golden-cheeked warbler and black-capped vireo using LiDAR and NAIP-CIR imagery at Balcones Canyonlands National Wildlife Refuge, TX (unpublished ASPRS chapter presentation)

- Fagan and DeFries, Measurement and Monitoring of the World's Forests, A Review and Summary of Remote Sensing Technical Capability, 2009–2015

  http://www.rff.org/RFF/Documents/RFF-Rpt-Measurement%20and%20Monitoring_Final.pdf