



# Lidar and GIS Applications and Examples

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# Outline

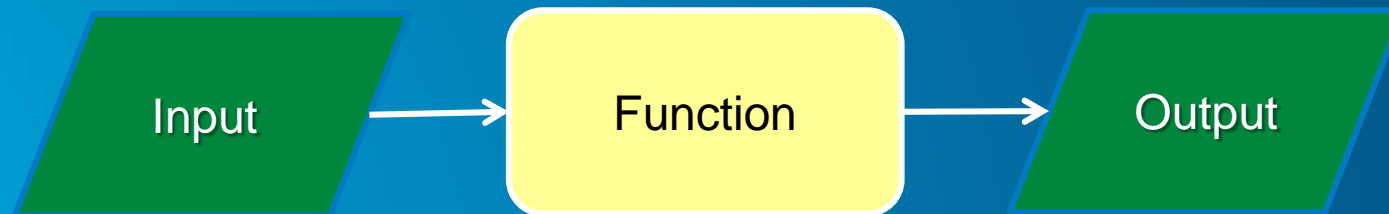
- **Data structures, tools, and workflows**
- **Assessing lidar point coverage and sample density**
- **Creating raster DEMs and DSMs**
- **Data area delineation**
- **Estimating forest canopy density and height**
- **Creating intensity images**
- **Reducing noise for contouring and slope analysis**
- **Floodplain delineation**

# Big Picture

- **Solutions for GIS end users**
  - **Not about lidar data production**
- **Operate on clean/classified lidar points**
- **Produce useful derivatives**
- **Perform analysis**
- **Handle large datasets**
- **Both file and database oriented solutions**

# Supporting Data structures and Tools

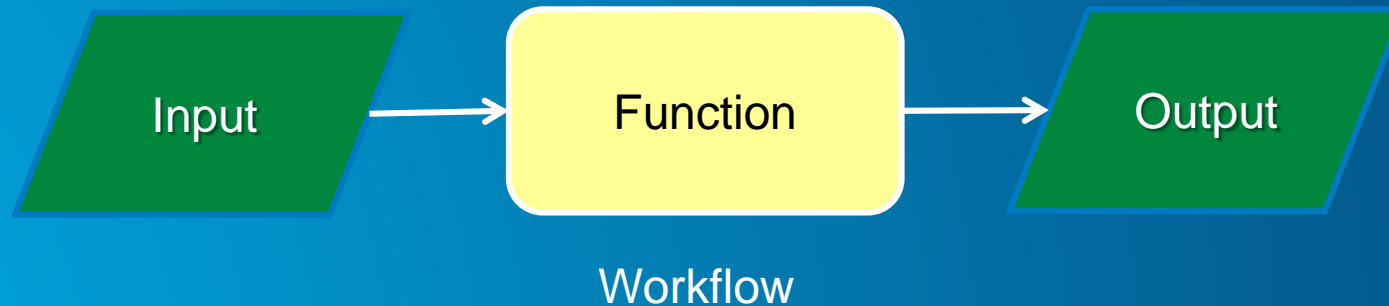
- **Vector features**
  - points
  - *multipoints*
  - lines
  - polygons
- **Raster**
- **TIN**
- *Terrain Dataset*
- **Point File Information**
- **LAS To Multipoint**
- **ASCII 3D To Feature Class**
- **Point To Raster**
- **Terrain To Raster**
- **Terrain To TIN**



Workflow

# Supporting Data structures and Tools (10.1)

- **LAS dataset**
  - LAS Dataset Statistics
  - LAS Dataset To Raster
  - LAS Point Statistics As Raster
  - LAS Dataset To TIN
- **Mosaic dataset**
  - Extensive collection of raster tools



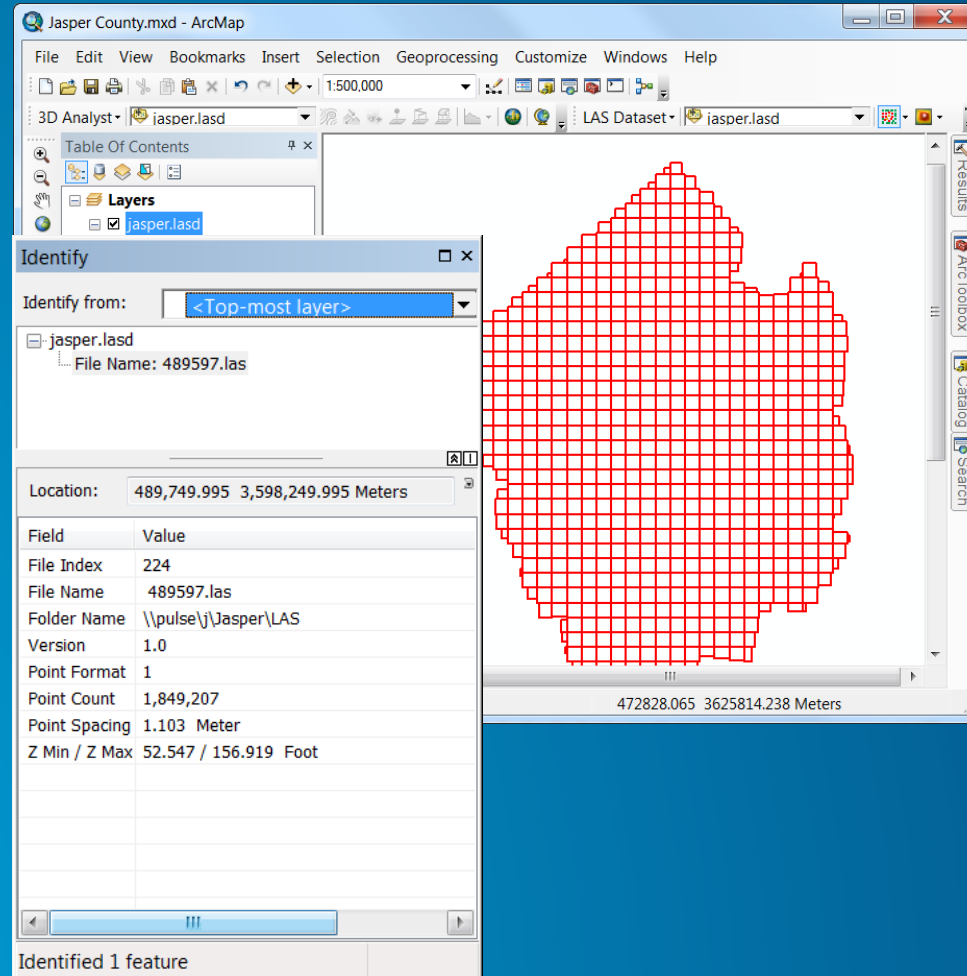
# Lidar point coverage and sample density

- Basic QA/QC before loading data into geodatabase
- Verify xy and z extent
- Examine point spacing

Name	Date modified	Type	Size
Tile000023.las	10/30/2008 12:13 ...	LAS File	264,438 KB
Tile000024.las	10/30/2008 12:14 ...	LAS File	367,523 KB
Tile000025.las	10/30/2008 12:15 ...	LAS File	340,340 KB
Tile000026.las	10/30/2008 12:16 ...	LAS File	85,184 KB
Tile000035.las	10/30/2008 12:22 ...	LAS File	132,955 KB
Tile000036.las	10/30/2008 12:23 ...	LAS File	485,083 KB
Tile000037.las	10/30/2008 12:24 ...	LAS File	390,750 KB
Tile000038.las	10/30/2008 12:25 ...	LAS File	350,254 KB
Tile000039.las	10/30/2008 12:26 ...	LAS File	255,534 KB
Tile000040.las	10/30/2008 12:26 ...	LAS File	147,637 KB

= ?

# LAS Dataset Layer (10.1)



# LAS Dataset Properties (10.1)

The image shows two overlapping dialog boxes from a software application. The background dialog is 'LAS Dataset Properties' and the foreground dialog is 'LAS File Properties and Statistics'. A red arrow points from the 'LAS File' column header in the background dialog to the 'Name' field in the foreground dialog.

**LAS Dataset Properties**

General | LAS Files | Surface Constraints | Statistics | XY Coordinate System | Z Coordinate System

Show: File  Show full path of LAS files

LAS File	Version	Point Count	Point Spacing	Z Min	Z Max
472599.las	1.0	206,405	1.246	18.06	157.55
472600.las	1.0	298,214	1.492	18.32	119.14
472602.las	1.0	188,594	1.585	18.39	101.39
474597.las	1.0	237,373	1.605	18.16	64.15
474599.las	1.0	1,904,058	1.087	18.06	128.23
474600.las	1.0	1,832,859	1.108	18.06	128.23
474602.las	1.0	1,961,049	1.072	27.34	157.55
474603.las	1.0	219,374	1.387		
475597.las	1.0	1,534,406	1.138		
475599.las	1.0	2,164,466	1.020		
475600.las	1.0	2,168,471	1.019		
475602.las	1.0	2,199,069	1.012		
475603.las	1.0	1,740,017	1.138		
475605.las	1.0	124,640	1.543		
477594.las	1.0	264,015	1.447		
477596.las	1.0	1,121,741	1.200		
477597.las	1.0	1,813,649	1.114		
477599.las	1.0	2,025,371	1.055		
477600.las	1.0	2,239,866	1.003		
477602.las	1.0	2,020,815	1.056		
477603.las	1.0	1,744,430	1.136		

**LAS File Properties and Statistics**

General

Name: 472599.las  
Version/Point Format: 1.0 / 1  
Point Count: 206,405  
Spatial Reference: NAD83\_UTM\_zone\_17N  
Date Created:  
X, Y, Z Offsets: 0.000000, 0.000000, 0.000000  
X, Y, Z Scale Factors: 0.010000, 0.010000, 0.010000  
Model Key Points: 0

Extent

Min X: 473542.340000 Max X: 473999.990000  
Min Y: 3599631.800000 Max Y: 3600330.690000  
Min Z: 18.063736 Max Z: 157.558634

X Range: 457.650000  
Y Range: 698.890000  
Z Range: 139.494898

XY Linear Unit: Meter  
Z Unit: Foot

Returns

Return	Point Count	%	Z Min	Z Max
First	129,818	62.89	18.06	157.55
Second	59,630	28.89	18.32	119.14
Third	15,504	7.51	18.39	101.39
Fourth	1,453	0.70	18.16	64.15
Last	128,658	62.33	18.06	128.23
Single	69,308	33.58	18.06	128.23
First of Many	60,510	29.32	27.34	157.55

Classification Codes

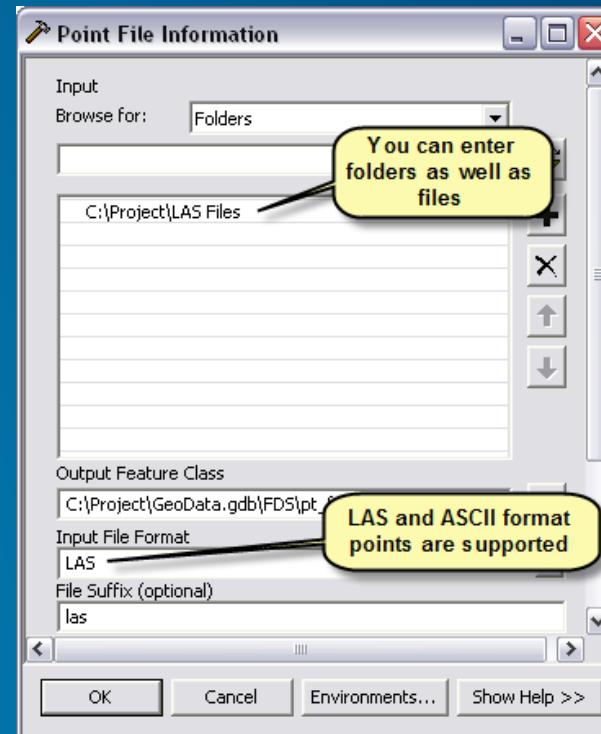
Classification	Point Count	%	Z Min	Z Max	Min Inten...	Max Inte...	Synthetic...
1 Unassigned	114,741	55.59	18.54	157.55	0	255	0
2 Ground	77,590	37.59	18.06	28.98	0	255	0
9 Water	14,074	6.82	18.27	27.82	0	255	0

Buttons: Previous File, Next File, Update, Force recalculate, OK



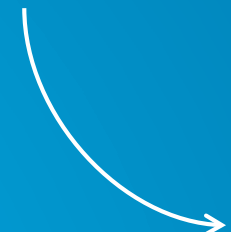
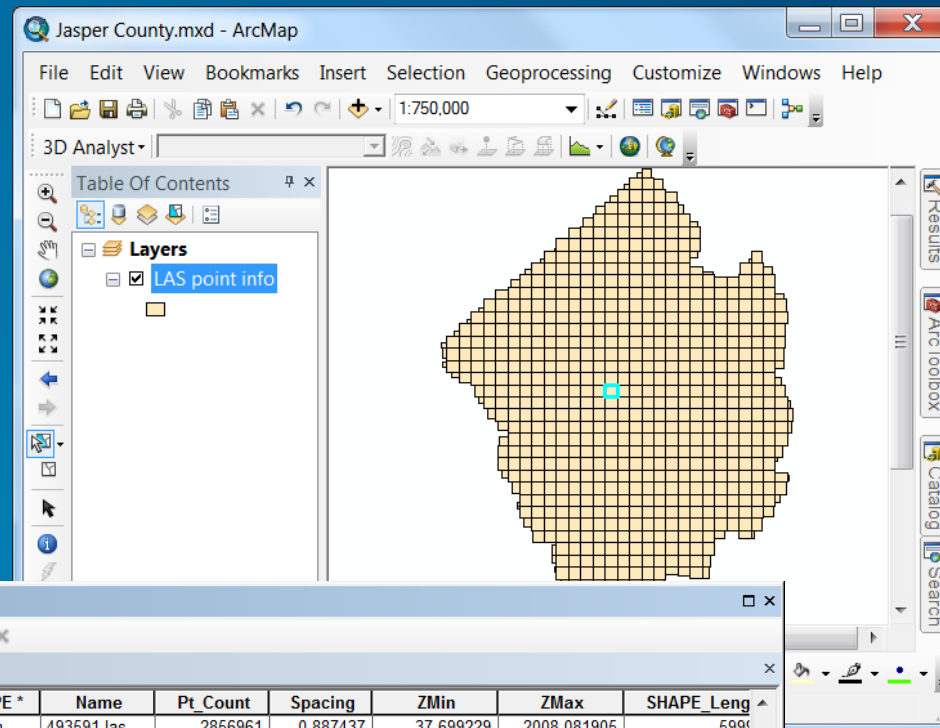
# Point File Information Tool

- Inputs files (LAS and ASCII) and folders of files and outputs a polygon feature class.
- Each output record includes
  - Polygon of file's data extent
  - Source filename
  - Point count
  - Point spacing estimate
  - Z min
  - Z max



# Point File Information Tool

Name	Date modified	Type	Size
Tile000023.las	10/30/2008 12:13 ...	LAS File	264,438 K
Tile000024.las	10/30/2008 12:14 ...	LAS File	367,523 K
Tile000025.las	10/30/2008 12:15 ...	LAS File	340,340 K
Tile000026.las	10/30/2008 12:16 ...	LAS File	85,184 K
Tile000035.las	10/30/2008 12:22 ...	LAS File	132,955 K
Tile000036.las	10/30/2008 12:23 ...	LAS File	485,083 K
Tile000037.las	10/30/2008 12:24 ...	LAS File	380,111 K

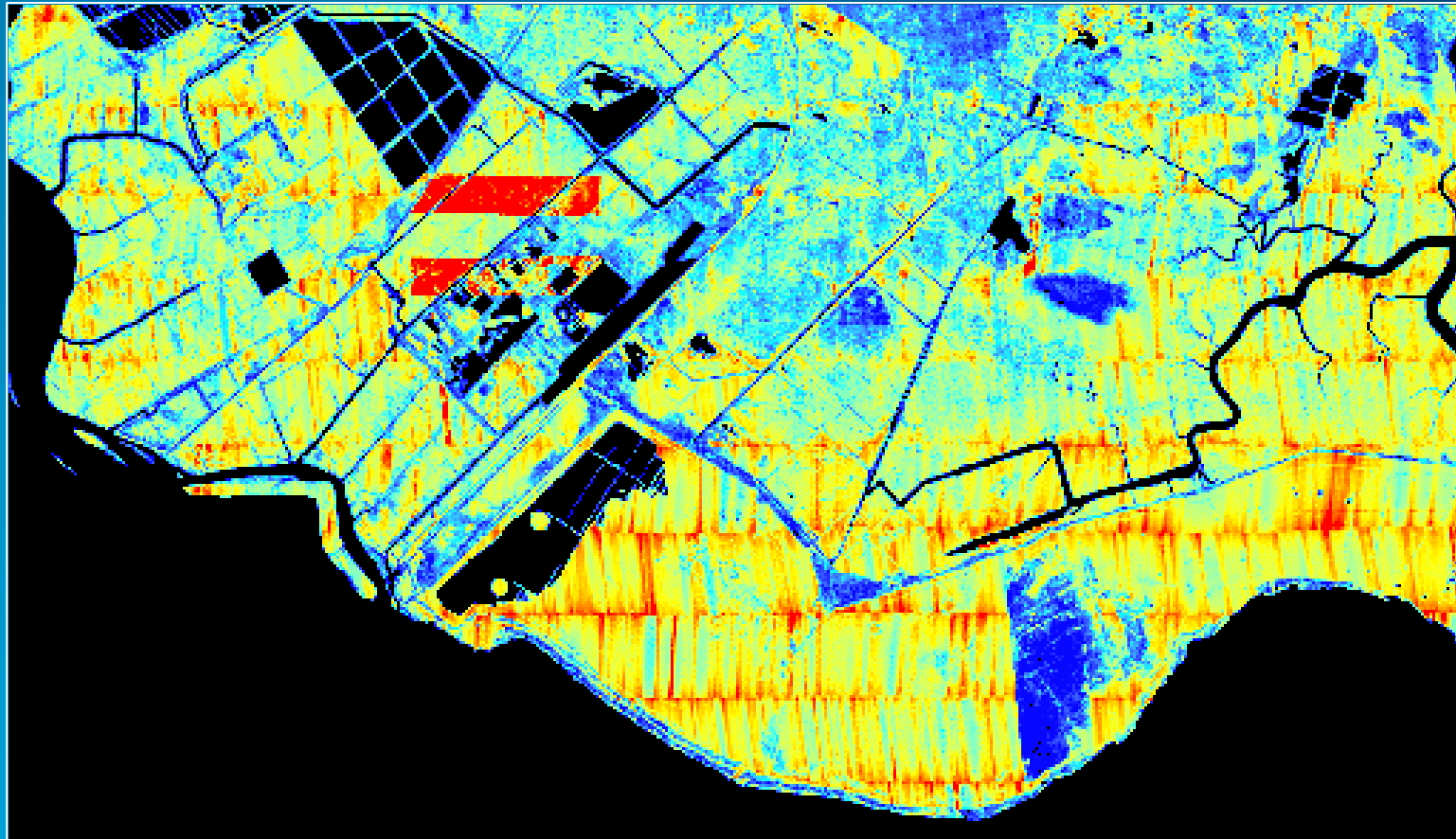


OBJECTID *	SHAPE *	Name	Pt_Count	Spacing	ZMin	ZMax	SHAPE_Leng
356	Polygon	493591.las	2856961	0.887437	37.699229	2008.081905	599...
357	Polygon	493593.las	1951547	1.073746	41.057551	165.782592	6...
358	Polygon	493594.las	2019437	1.055536	26.587318	4057.261696	599...
359	Polygon	493596.las	1691486	1.153332	15.298815	169.309143	599...
360	Polygon	493597.las	1681189	1.156858	44.958778	172.64269	599...
361	Polygon	493599.las	1838707	1.106196	49.608659	169.238532	599...

(1 out of 880 Selected)

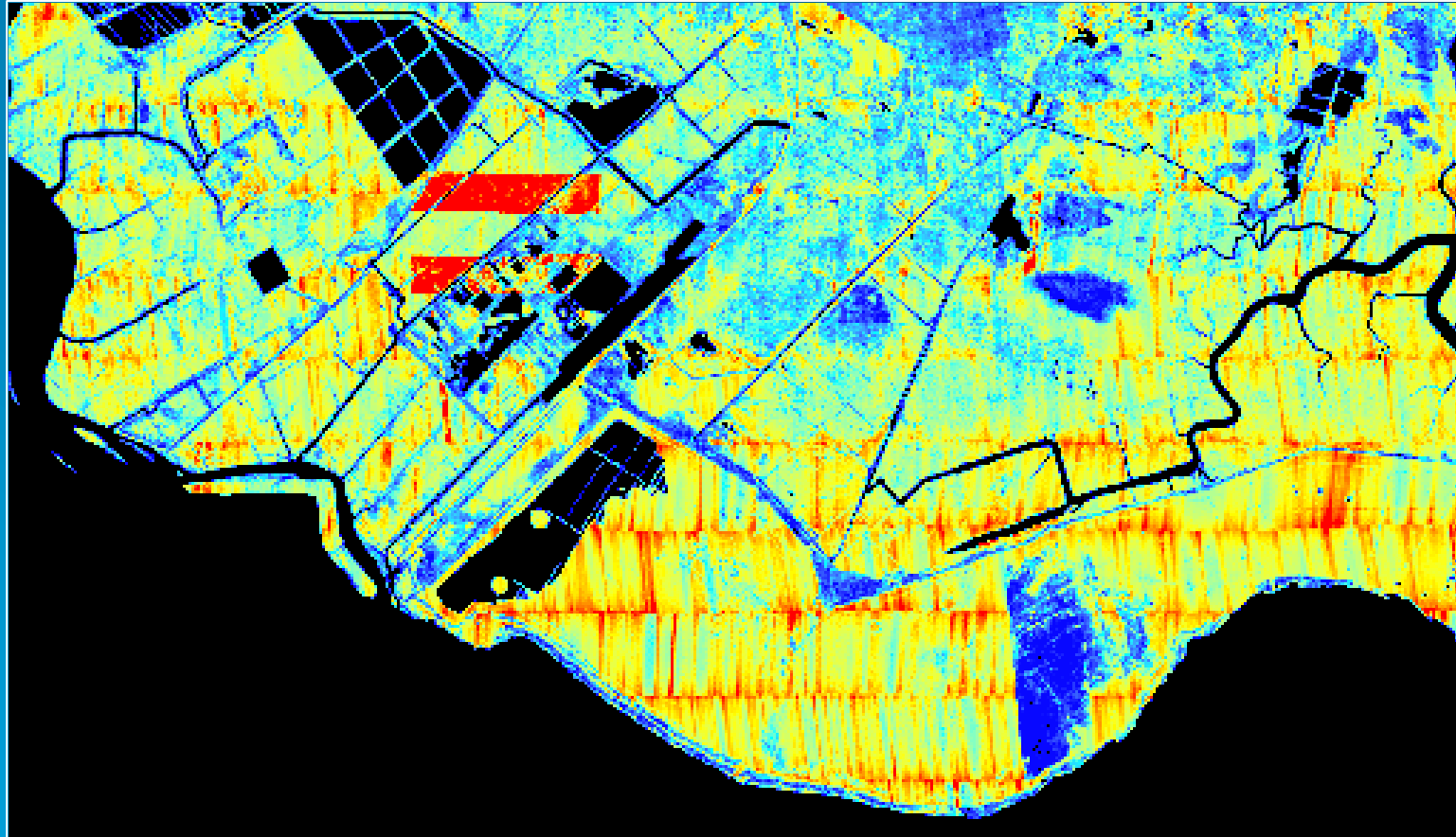
# LAS Point Statistics As Raster Tool (10.1)

Pulse/sample density



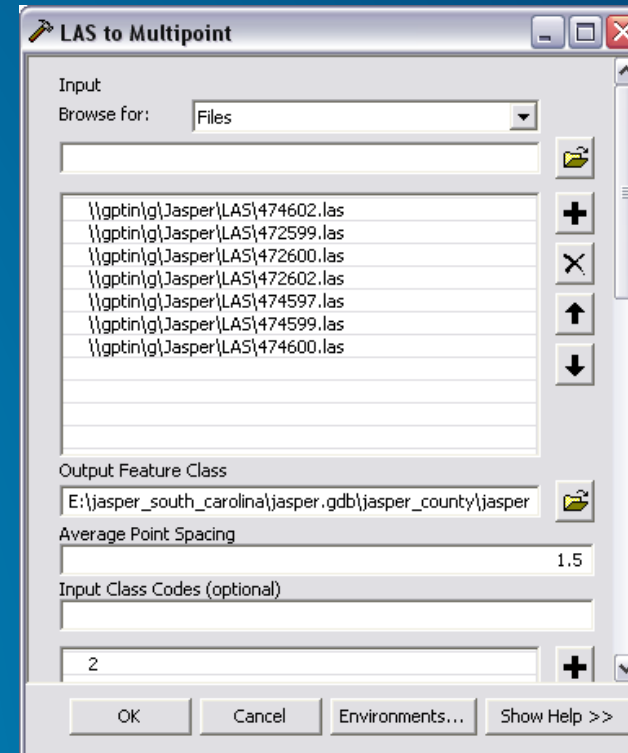
# Point To Raster Tool

Pulse/sample density



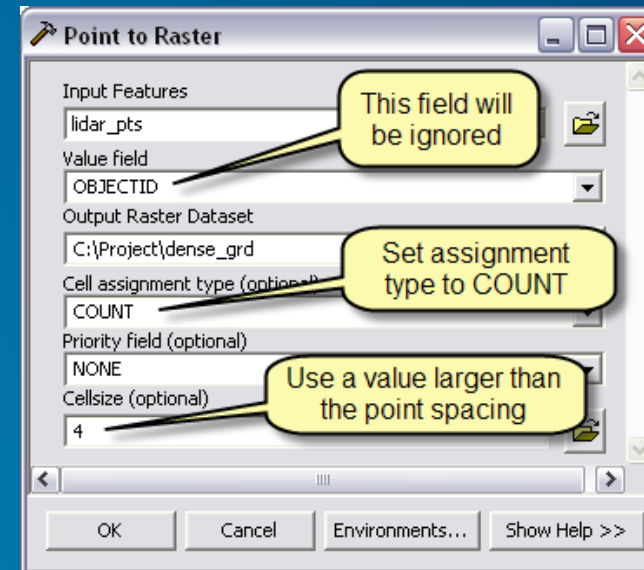
# Loading Data: LAS To Multipoint Tool

- LAS = industry standard file format for lidar
- Multipoints used for efficiency
- Filter options
  - By class
  - By return



# Point to Raster Tool

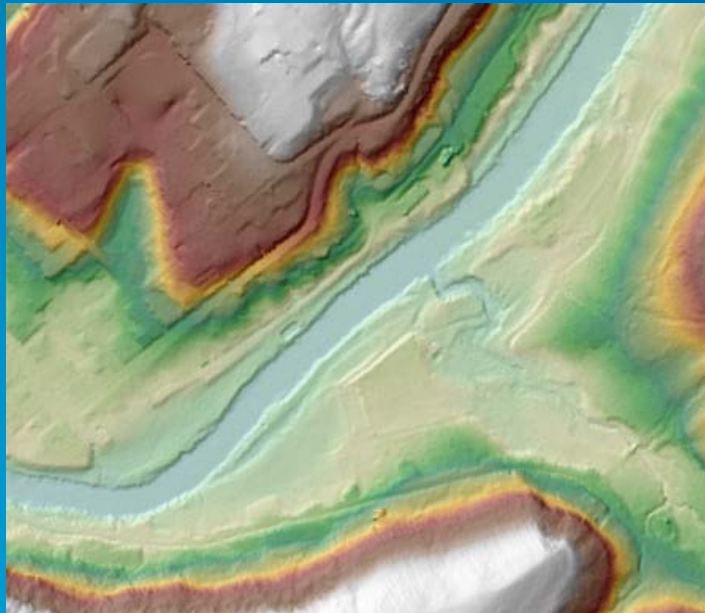
- Used after points are loaded into geodatabase
- More detailed assessment than Point File Information
- Based on actual points loaded (i.e., filtered by class code or return) rather than summary of entire file.



**Demo**

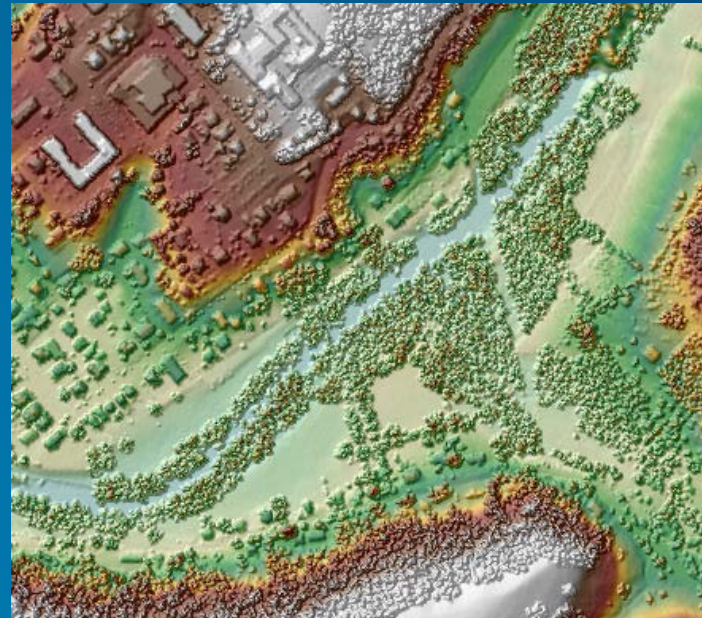
# Creating Raster DEMs and DSMs

Digital Elevation Model



Bare earth surface made using only ground hits.

Digital Surface Model

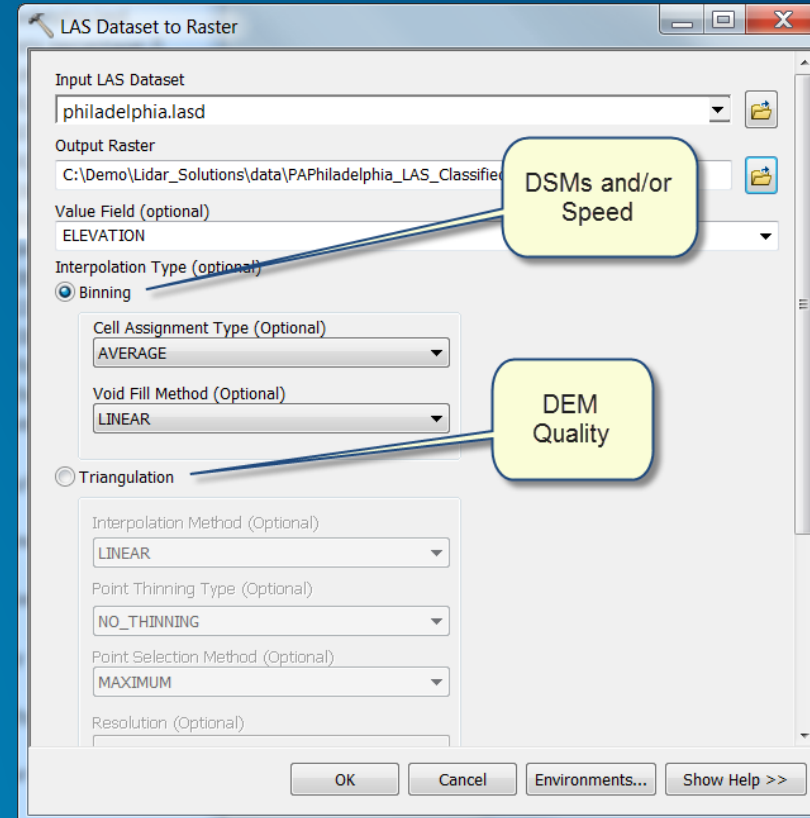


Includes ground, trees, and buildings made using first returns.



# LAS Dataset To Raster (10.1)

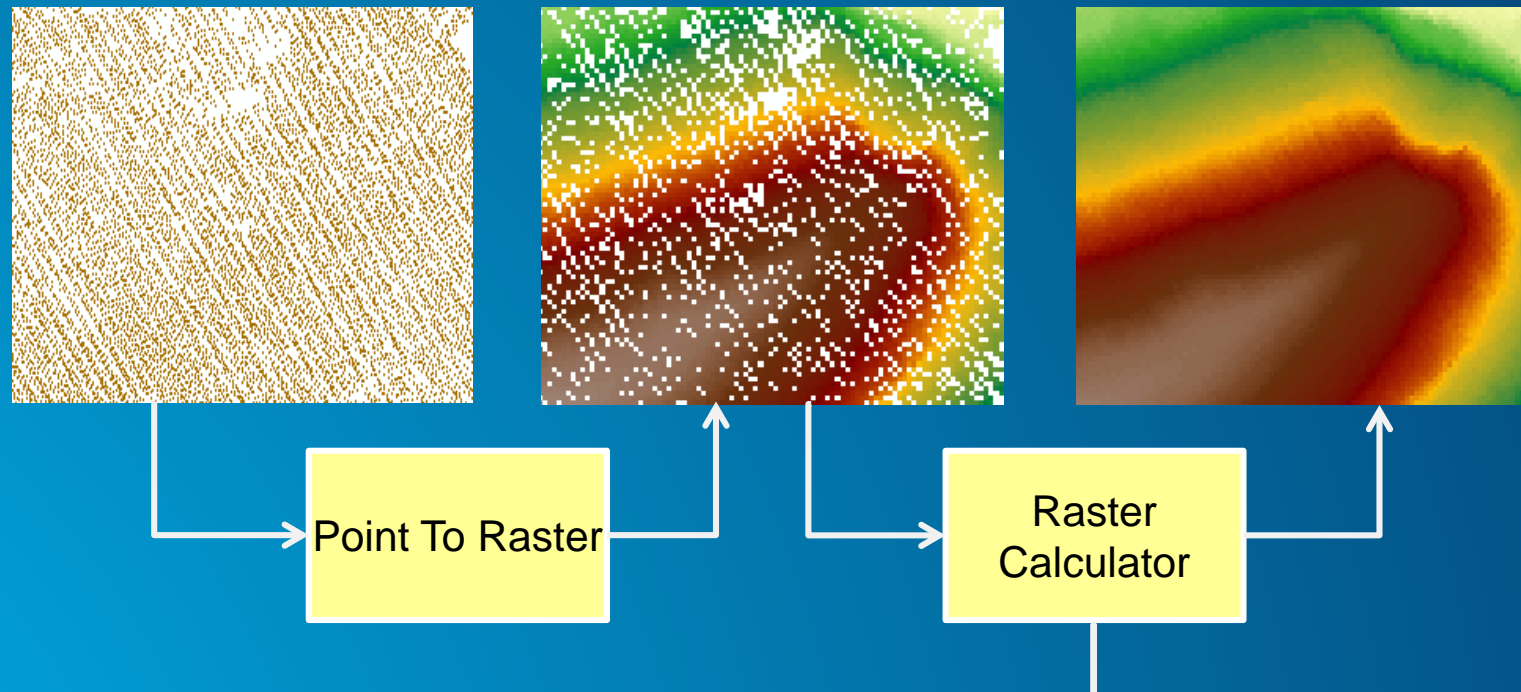
- **Binning**
  - **Fast**
  - **Reasonable for DSMs**
  - **Void filling options**
  - **Honors replace and clip constraint types**
- **Triangulation**
  - **True interpolation**
  - **Always fills voids**
  - **Appropriate for DEMs**
  - **Honors all constraint types**



# Point to Raster Tool

- *Fast*
- Rasterize based on multipoint vertex z
- Not true interpolation
- Doesn't support breaklines
- Data gaps
- Arguably works best with 1<sup>st</sup> return data because there are fewer and smaller data voids to deal with.

# Point to Raster Post-process: Void Filling

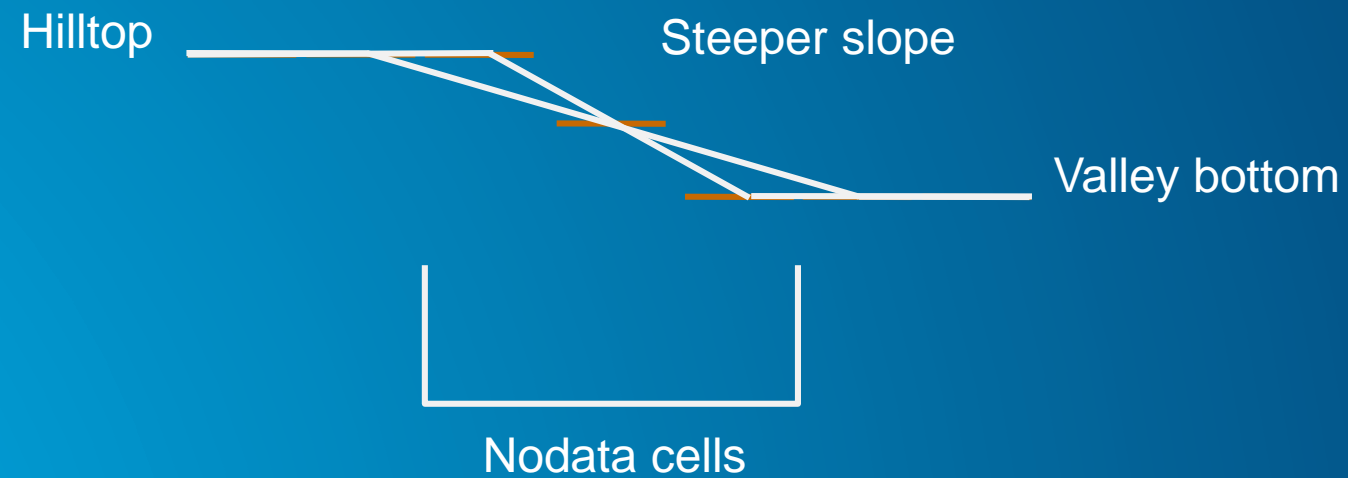


```
Con(IsNull("pt2ras"), FocalStatistics("pt2ras", NbrRectangle(3, 3, "CELL"), "MEAN", "DATA"), "pt2ras") 10.0
```

```
Con(IsNull([pt2ras]), FocalMean([pt2ras], Rectangle, 3, 3, DATA), [pt2ras])
```

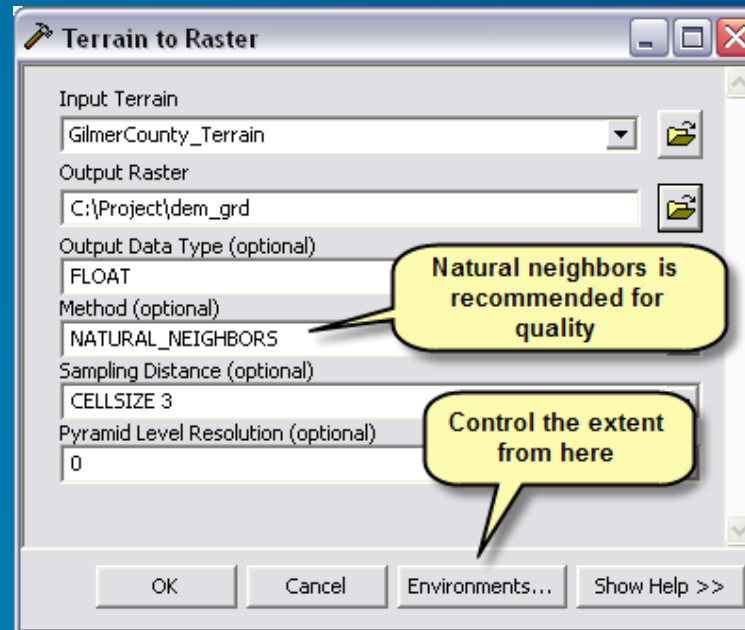
# Don't Abuse Con

- Introduces anomalies if used repeatedly



# Terrain to Raster

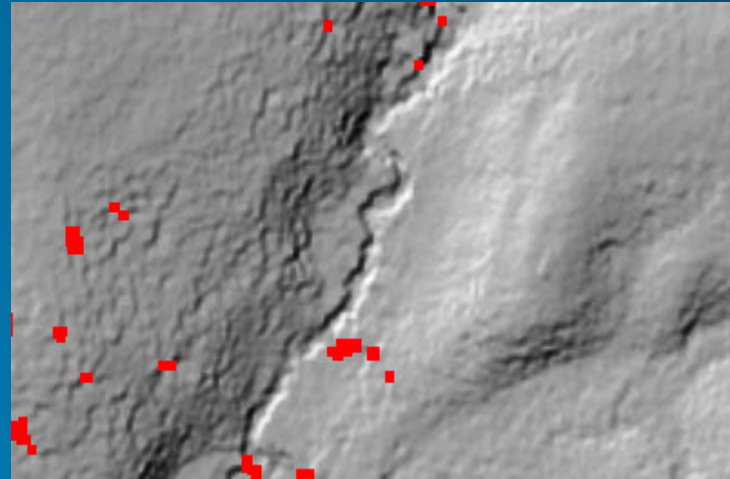
- *Quality*
- Supports ancillary data (breaklines, water bodies, etc.)
- True interpolation
- Can handle large datasets



# Comparison

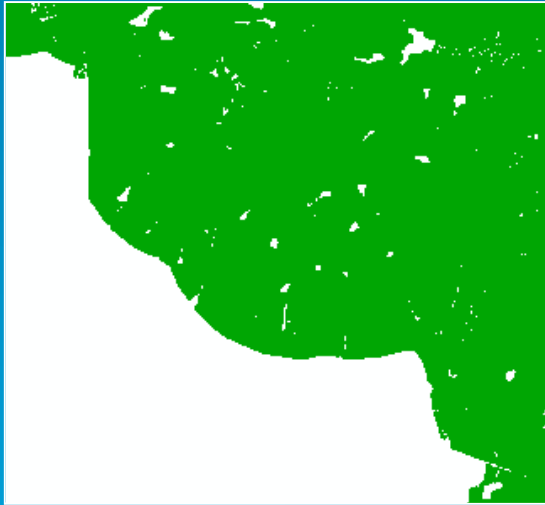


Interpolation

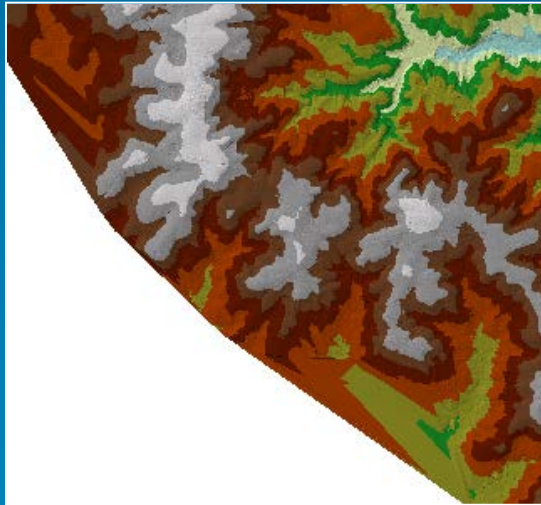


Binning

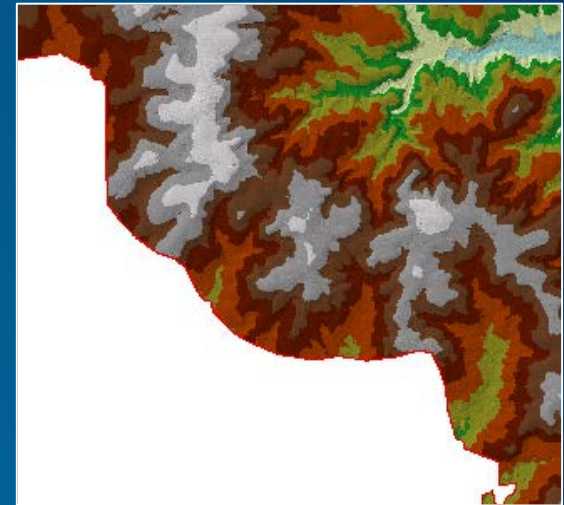
# Data Area Delineation



Dense collection of source measurement points (green)

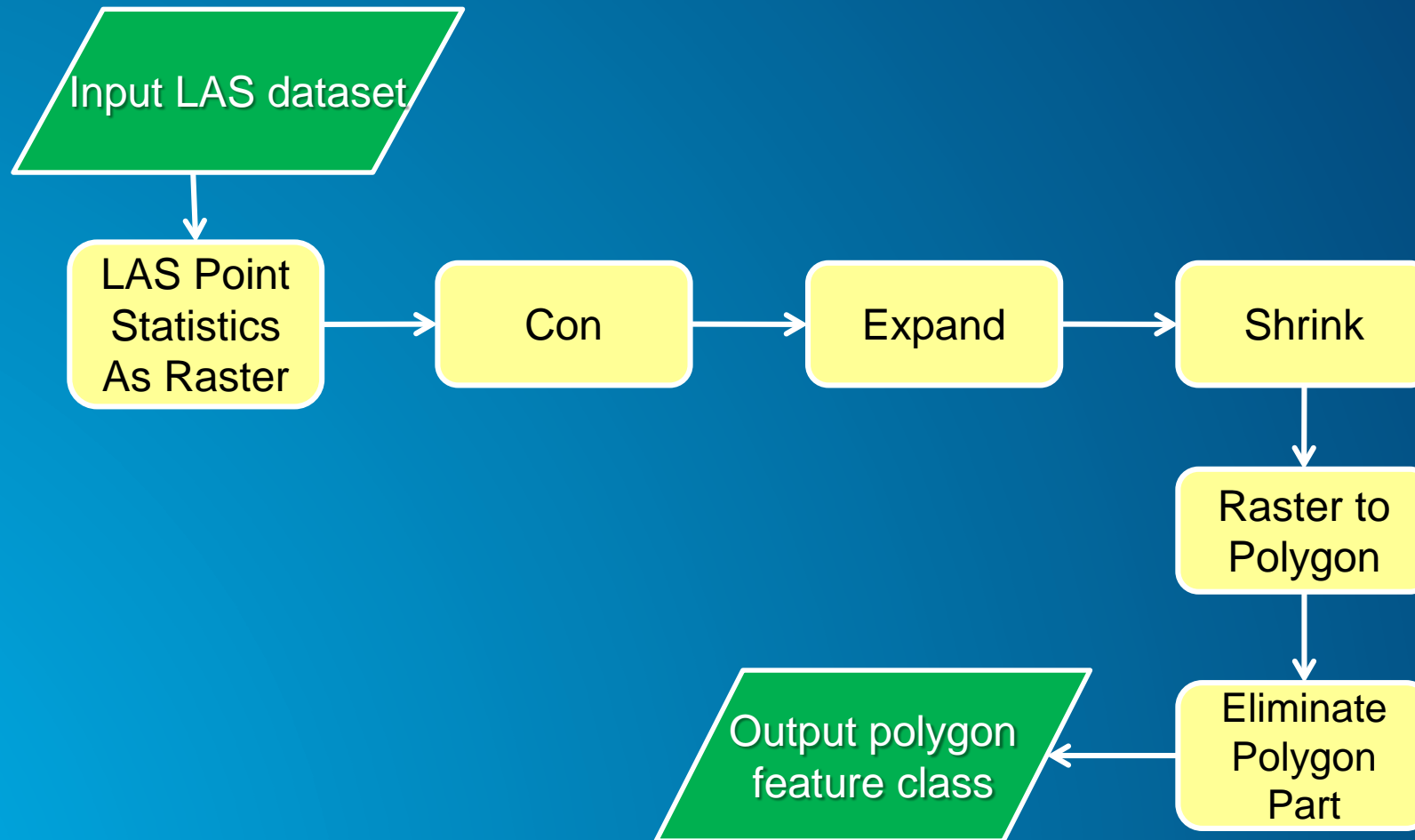


Triangulation of those points without a boundary constraint



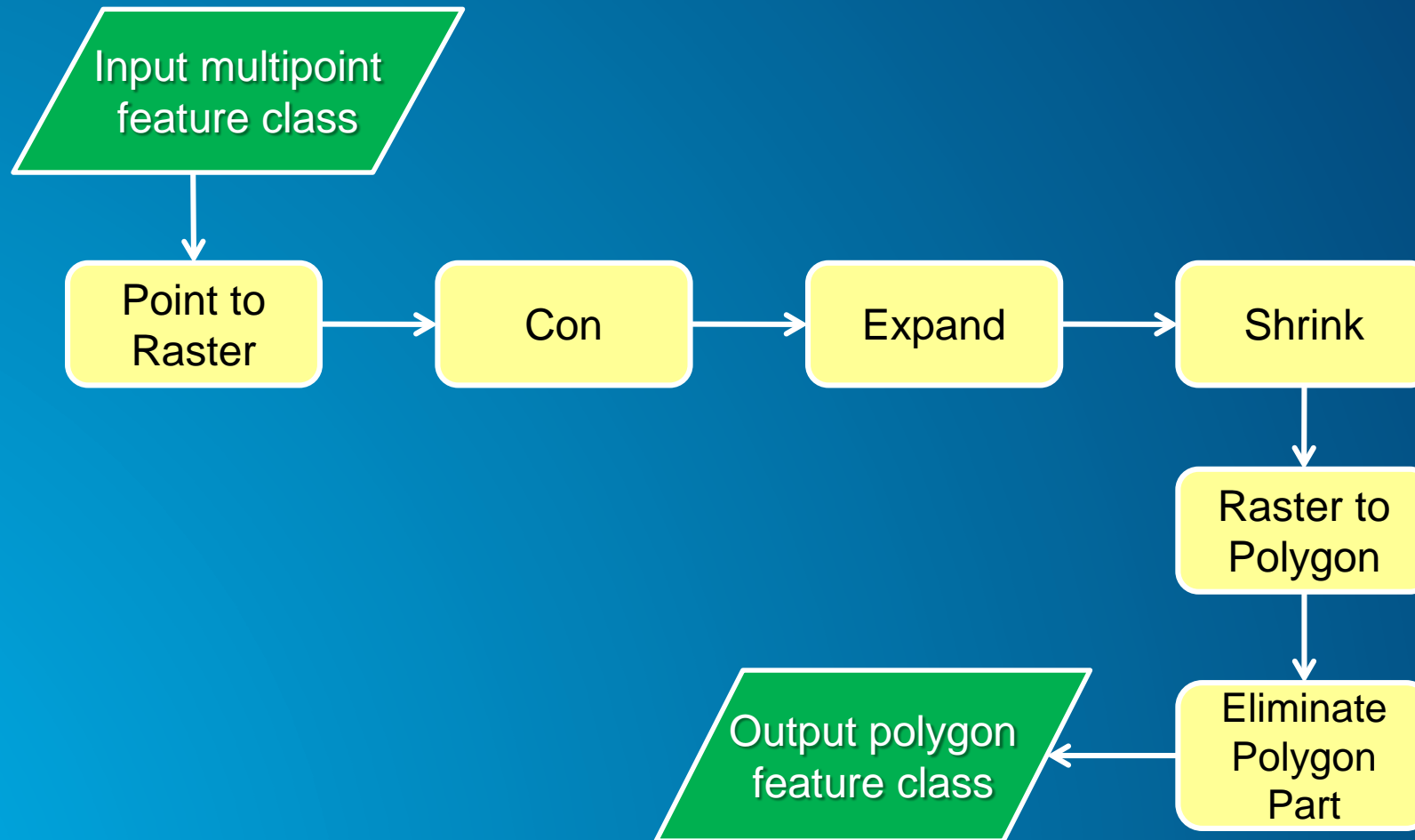
Constraint applied

## Workflow to Calculate a Data Area Polygon (10.1)



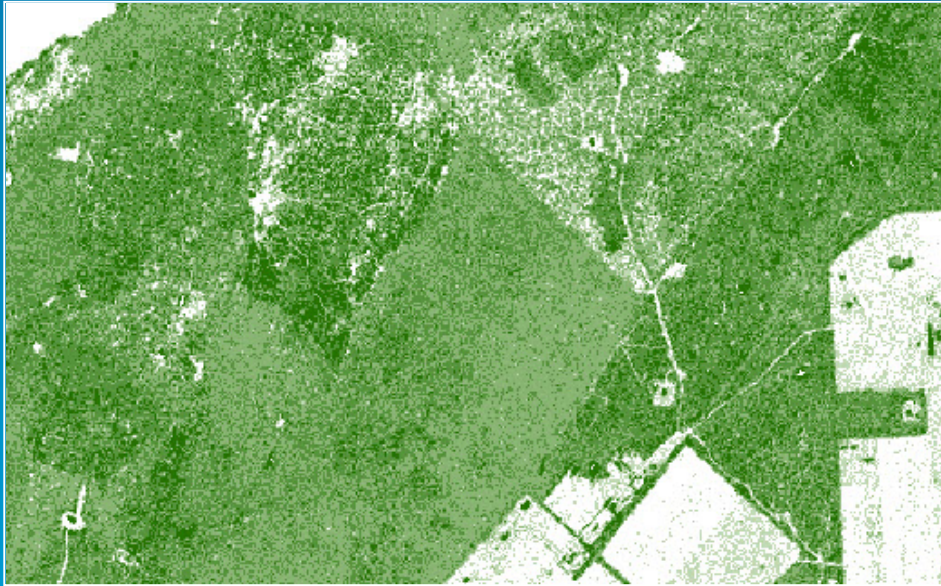


# Workflow to Calculate a Data Area Polygon



**Demo**

# Estimating Forest Canopy Density and Height

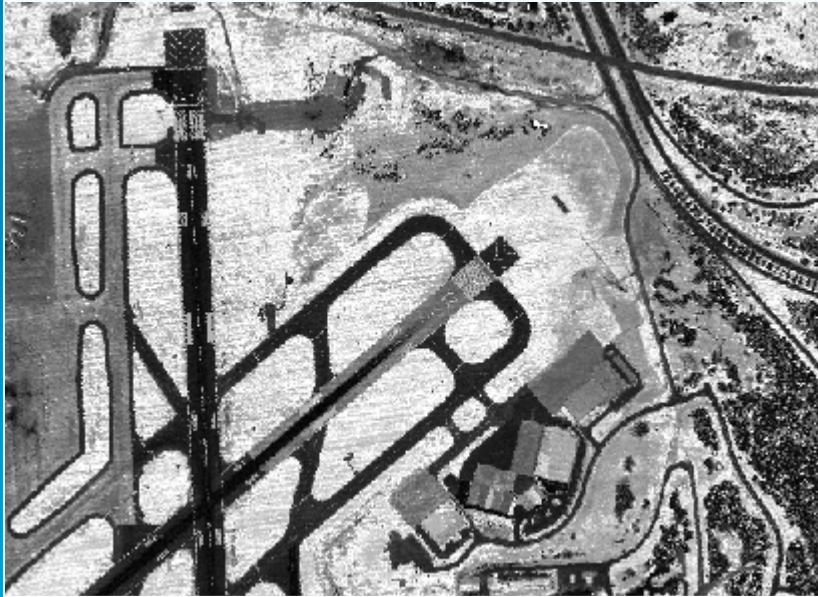


**Height (meters)**  
**Value**  
High : 38.45  
Low : 0

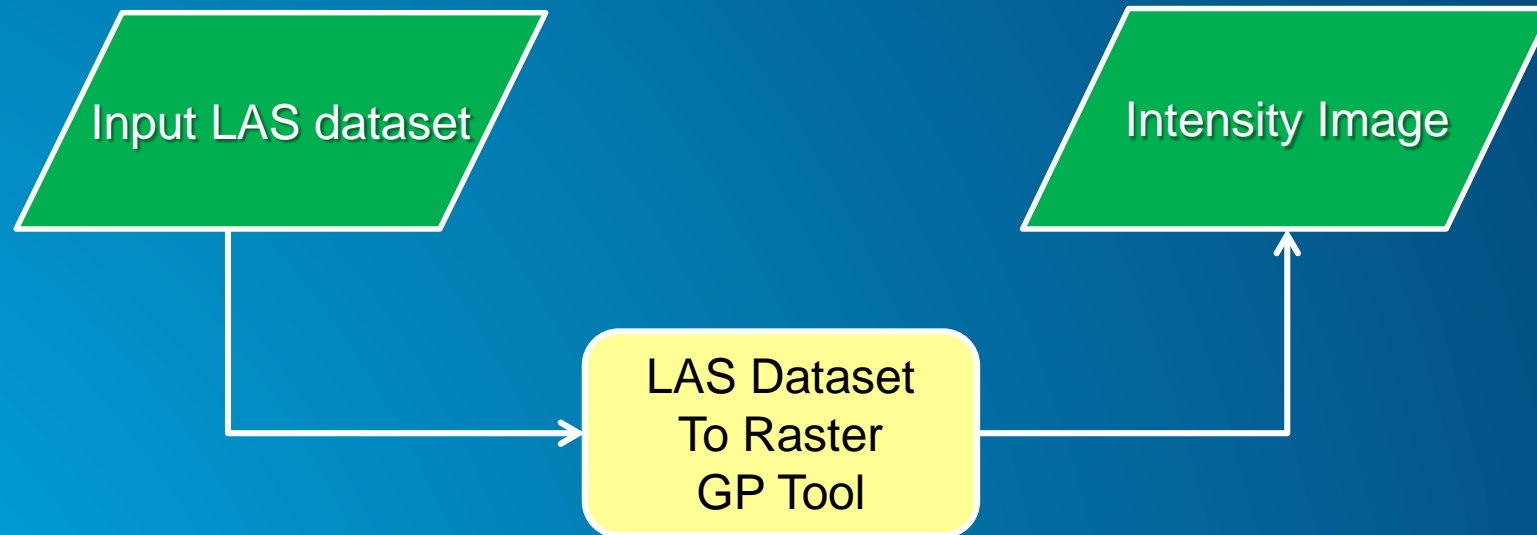
# Canopy Density and Height

- **Density is the ratio of vegetation hits to total hits within a unit area (i.e., raster cell).**
  - **LAS to Multipoint to make two feature classes: ground and non-ground.**
  - **Point to Raster to make 'count' grids.**
  - **10.1 or later can use LAS Point Statistics As Raster to make 'count' grids**
  - **Add ground and non-ground to make a 'total' grid.**
  - **Use Divide to get the ratio between non-ground and total.**
- **Height is the difference between DSM and DEM**
  - **Use Point to Raster or Terrain to Raster followed by Minus.**

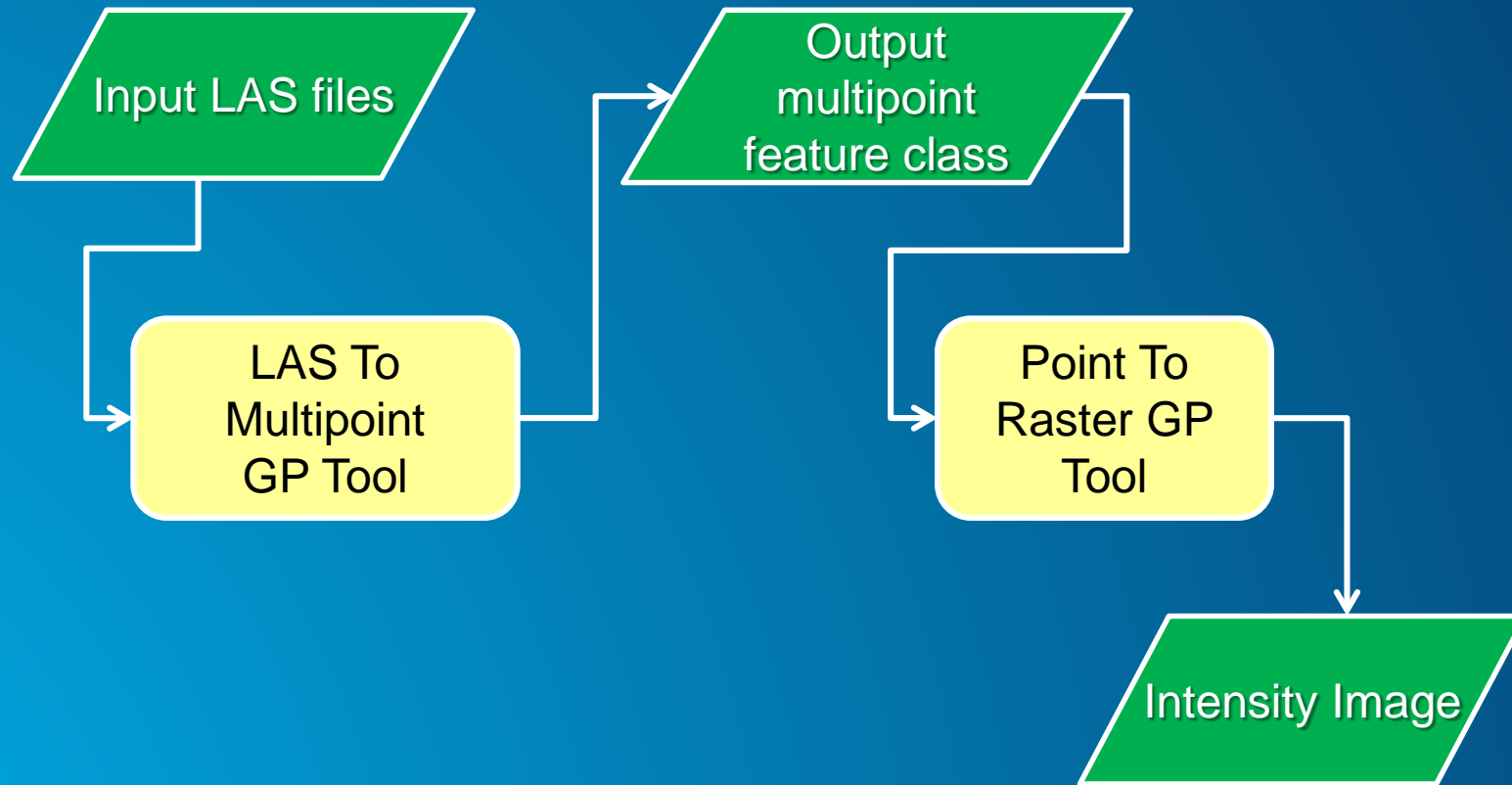
# Creating Intensity Images



## Intensity Image Workflow (10.1)



# Intensity Image Workflow



# BLOB Based Storage of Intensity

The image shows two windows from a GIS application. The 'LAS to Multipoint' dialog box on the left has a dropdown menu for 'Input Attribute Names (optional)'. A yellow callout box points to this dropdown with the text: 'Select 'Intensity' from this dropdown list as an attribute to load in from the LAS file(s)'. Below the dropdown is a table with two columns: 'Keyword' and 'Name'. The first row contains 'INTENSITY' and 'Intensity'. The 'Attributes of first\_return\_points' window on the right displays a table with four columns: 'OID \*', 'Shape ^', 'Intensity', and 'PointCount'. The 'Intensity' column contains the value 'Blob' for all 11 rows. The 'PointCount' column contains the value '3500' for all 11 rows. A white arrow points from the 'Intensity' column header in the table to the 'Intensity' keyword in the dialog box's table.

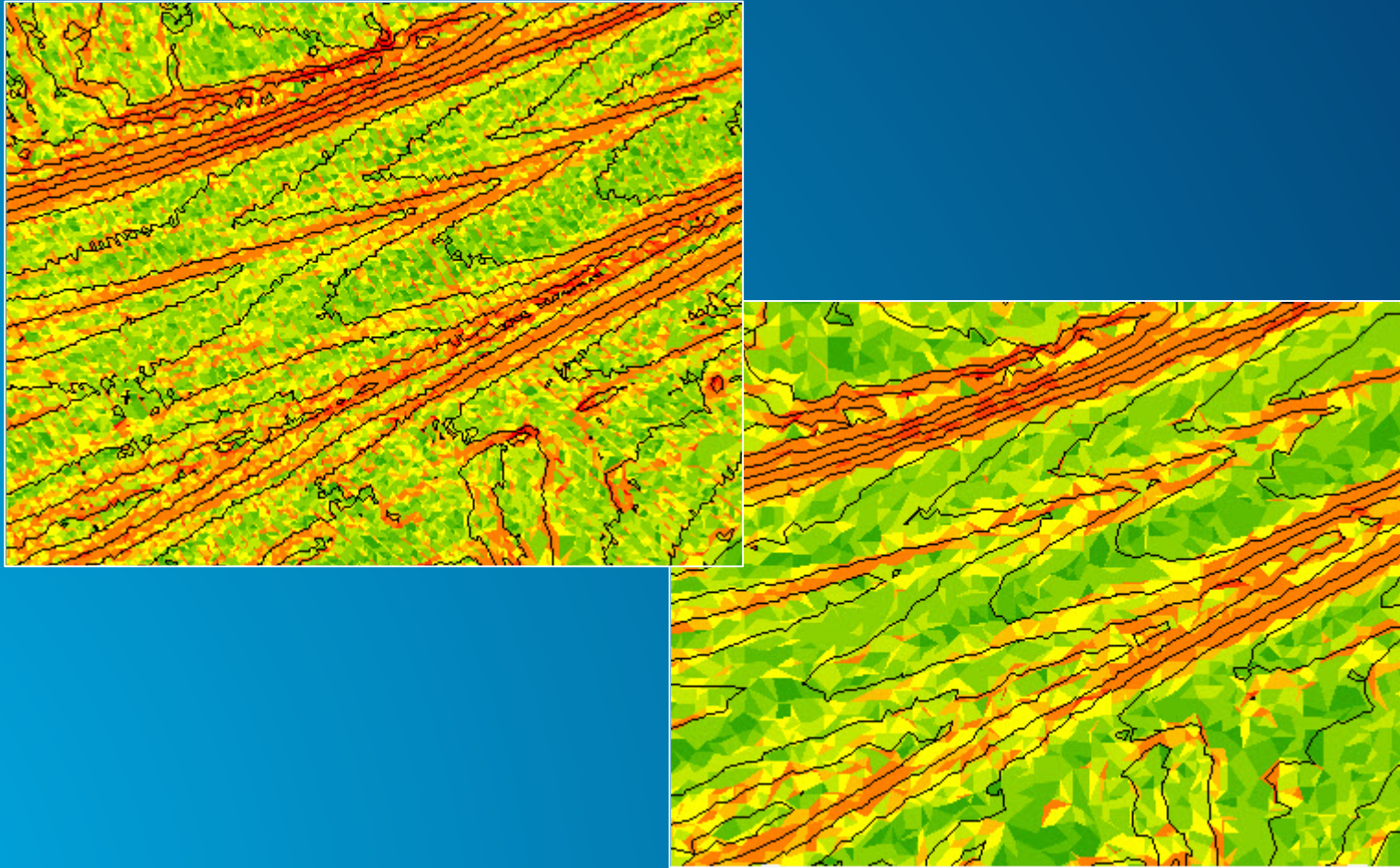
Keyword	Name
INTENSITY	Intensity

OID *	Shape ^	Intensity	PointCount
1	Multipoint Z	Blob	3500
2	Multipoint Z	Blob	3500
3	Multipoint Z	Blob	3500
4	Multipoint Z	Blob	3500
5	Multipoint Z	Blob	3500
6	Multipoint Z	Blob	3500
7	Multipoint Z	Blob	3500
8	Multipoint Z	Blob	3500
9	Multipoint Z	Blob	3500
10	Multipoint Z	Blob	3500
11	Multipoint Z	Blob	3500

BLOBs are used, in the context of lidar, to store multiple numeric values together in one thing. Each BLOB contains as many values as there are vertices in the corresponding multipoint.



# Reducing Noise for Contouring and Slope Analysis



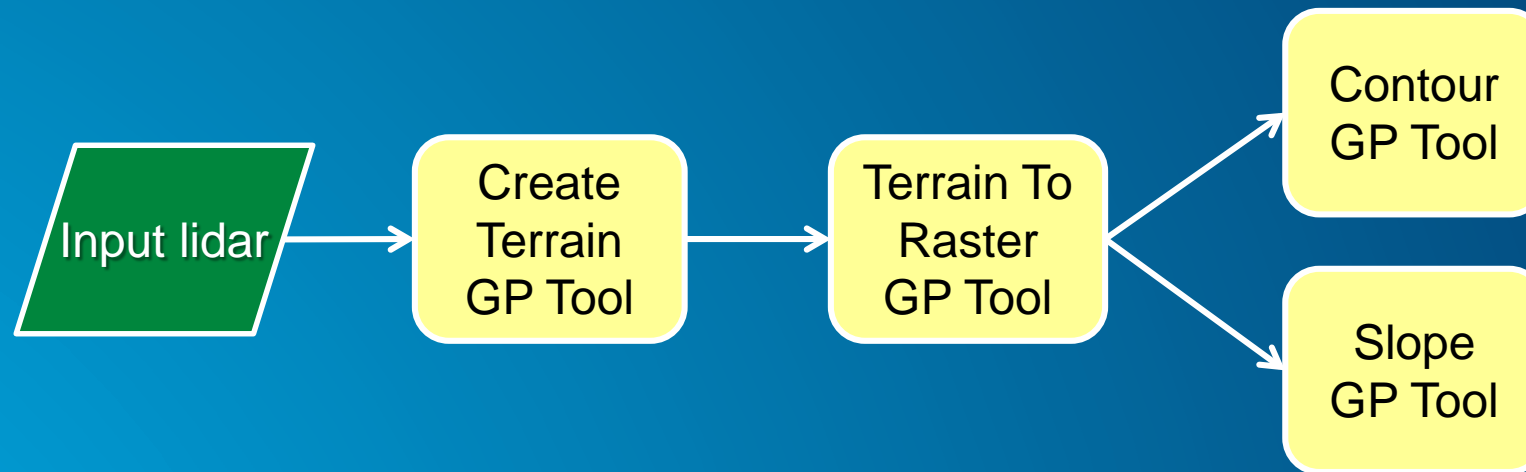
# Lidar Is Noisy

- Lidar has measurement error
- Typically 12-15cm vertical accuracy
- Horizontal sample density is often 1m or less
- This results in high frequency noise
  - Extremely messy contours
  - Average slope skewed to be very high
- Goal is to reduce noise without degrading the accuracy

# Point Thinning, Interpolation, and Rasterization

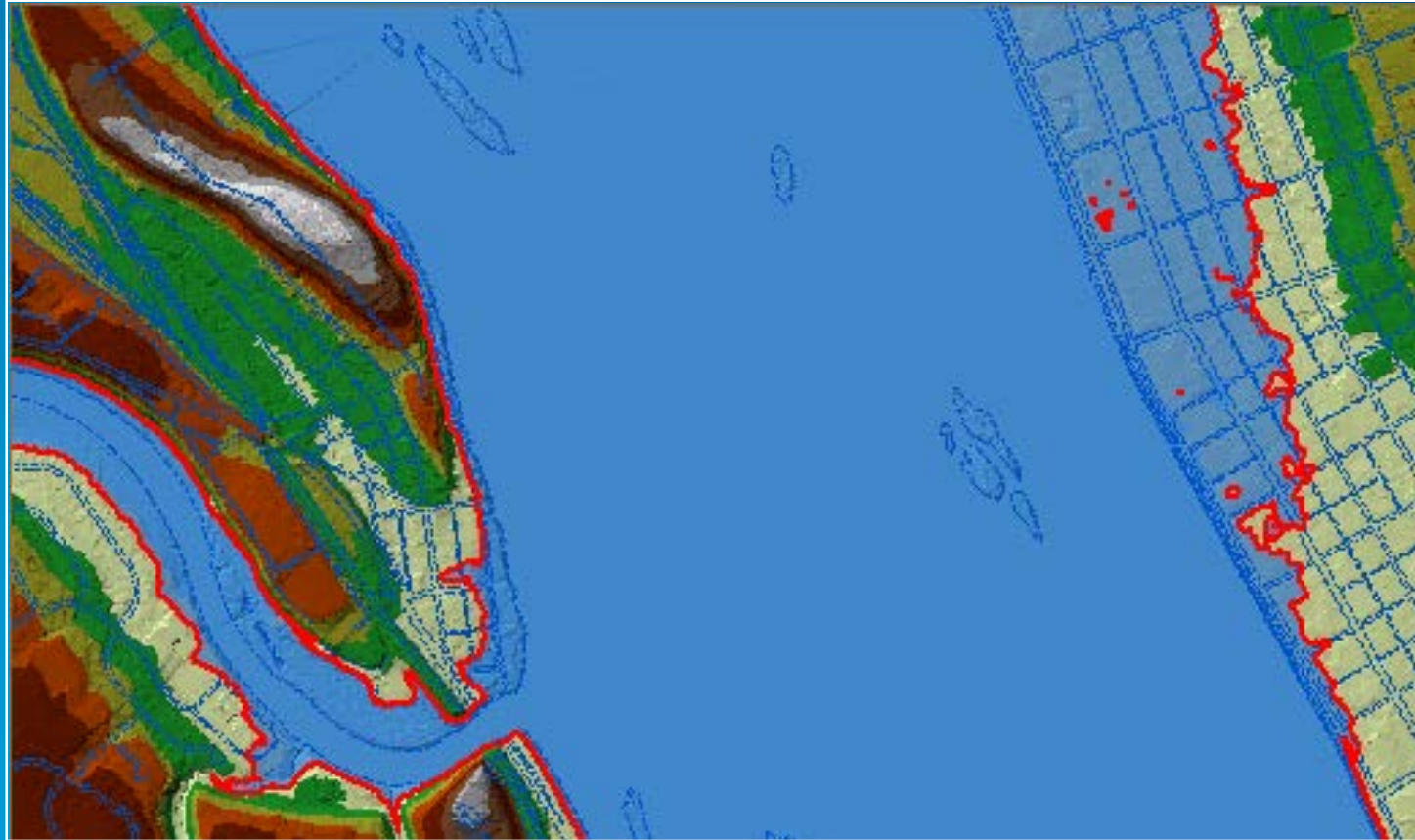
- Use only those points necessary
- Some applications refer to points selected for use in making contours as 'model key' points
- Terrain pyramids
  - Original points filtered into different levels of detail
  - Can specify which pyramid level to use when interpolating to raster or extracting TIN
- Natural neighbors
  - Conservatively smooth

# Point Thinning, Interpolation, and Rasterization



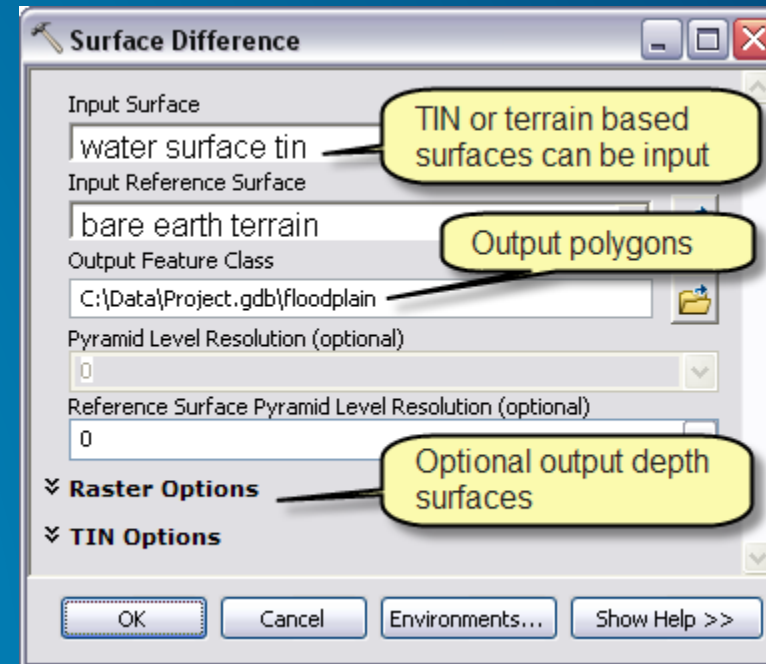
Workflow

# Floodplain Delineation



# Surface Difference Tool

- Subtract lidar based ground surface from modeled (e.g., HEC-RAS) water surface
- Output polygons used to delineate floodplain
- Optional output of depth surface(s)



**Demo**

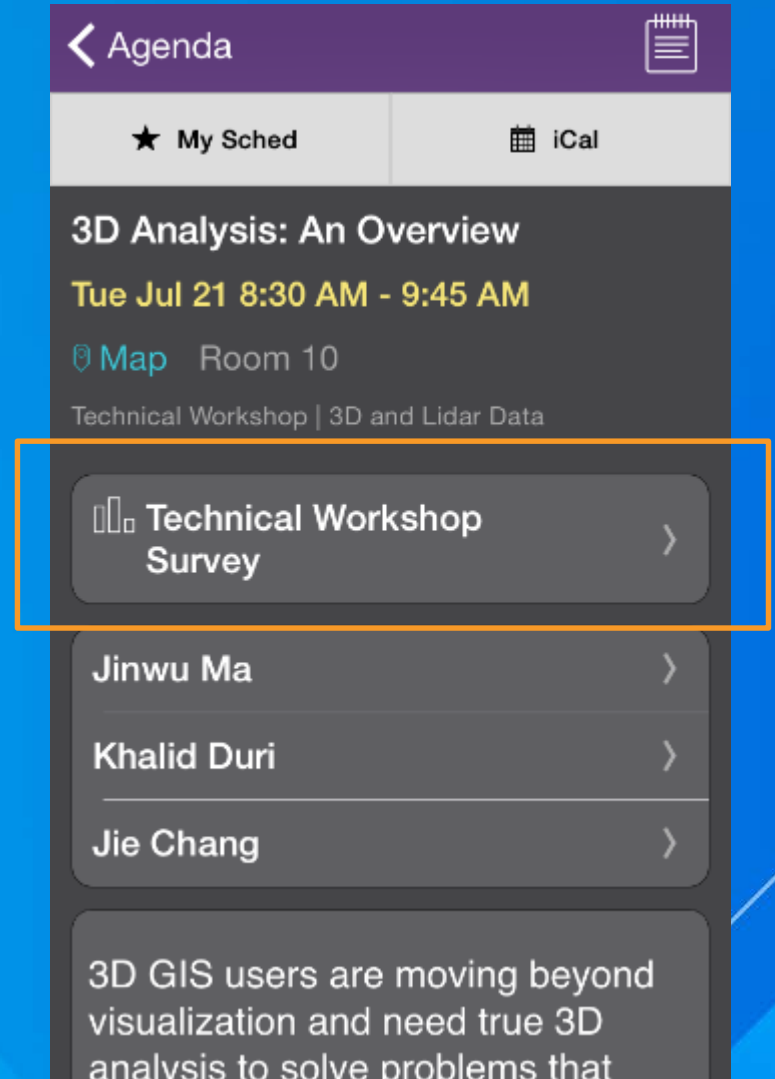
**For those wanting models:**

**Email: [ccrawford@esri.com](mailto:ccrawford@esri.com)**



# Thank you...

- Please fill out the session survey in your mobile app
- Select 'Lidar and GIS: Applications and Examples' in the Mobile App
  - Use the Search Feature to quickly find this title
- Click "Technical Workshop Survey"
- Answer a few short questions and enter any comments





Understanding our world.