3D Mapping with Lidar Point Clouds

Hands On Workshop

Using *ArcGIS® Pro 2.0*

THE SCIENCE OF WHERE™

Exercise 1: Extracting Building Footprints from Classified Lidar

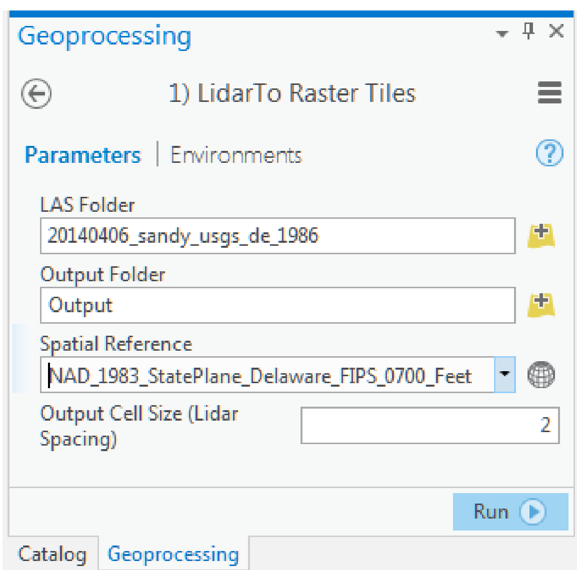
The Extracting Lidar Buildings workflow provides you with a set of geoprocessing tools that make it simple to create building footprints from lidar. The workflow can accommodate both lidar that is classified for buildings and unclassified for buildings. Both processes do the following:

- Convert the lidar to rasters
- Create mosaic datasets to manage the rasters
- Apply function chains to the mosaic datasets
- Convert the footprints to polygons
- Clean the polygons with tools

The result is rarely perfect but, for quick building extraction with some clean up, works well.

Part 1:

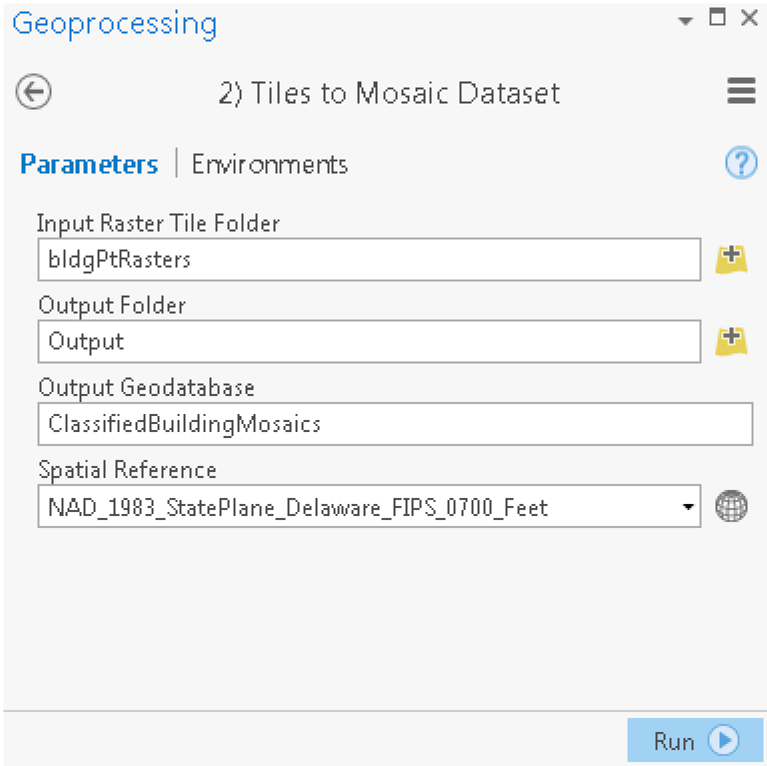
1. Double-click the **LidarBuildingExtraction** project file to open it in ArcGIS Pro.
2. Sign in using your ArcGIS Online Organization credentials.
3. On the **View Tab**, open the Catalog pane. Expand **Toolboxes** and the **ExtractBuildingFootprintsFromLidarClassifiedForBuildings_6_2_2017** toolbox.
4. Double-click **1) Lidar to Raster Tiles** to open the tool in the Geoprocessing pane.
5. Set the tool parameters as follows:
   - **LAS Folder**: Click the Browse button and select **20140406_sandy_usgs_de_1986**
   - **Output Folder**: Type **Output** into the box
   - **Spatial Reference**: Click the dropdown and select **Current Map [Classified Lidar]**
   - **Output Cell Size**: Use the default **2**
6. Click **Run** to create a folder containing a raster with pixels classified as buildings.



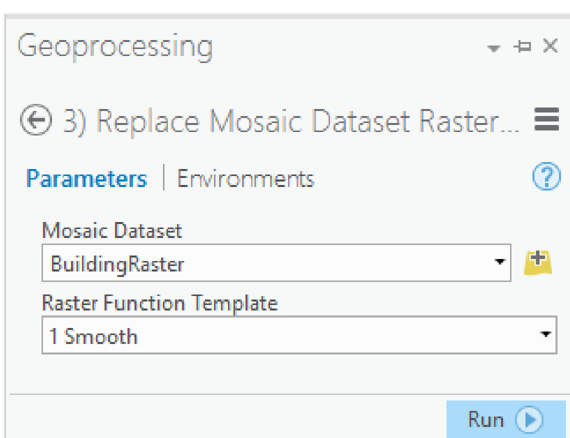
7. Return to the Catalog pane. Double-click **2) Tiles to Mosaic Dataset.**
8. Set the tool parameters as follows:
   - **Input Raster Tile Folder:** Click the Browse button to select the **bldgPtRasters** folder (located inside the **Output** folder that you created with the first tool)

- **Output Folder:** Click the Browse button and select **Output**
- **Output Geodatabase:** Leave the default name **ClassifiedBuildingMosaics**
- **Spatial Reference:** Click the dropdown and select **Current Map [Classified Lidar]**

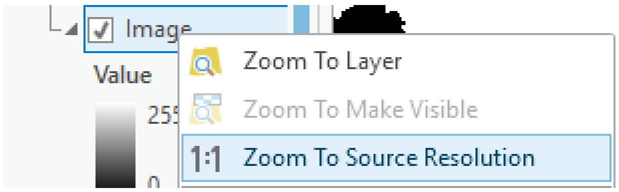
9. Click **Run** to create a mosaic dataset from the tiled rasters and add the it to the display.



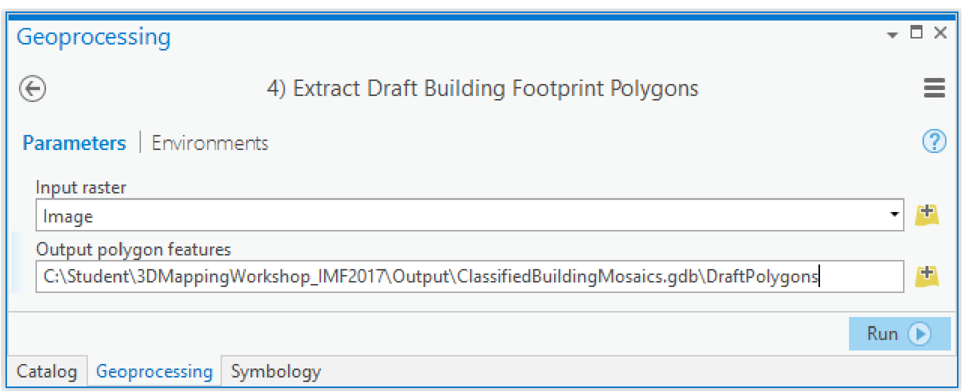
10. In the Contents pane, turn off the **20140406_sandy_usgs_de_1986.las** layer to better see the mosaic dataset.
11. Return to the Catalog pane. Double-click **3) Replace Mosaic Dataset Raster Function Template**.
12. Set the tool parameters as follows:
    - **Mosaic Dataset:** Click the dropdown and select **BuildingRaster**
    - **Raster Function Template:** Click the dropdown and select **1 Smooth**
13. Click **Run** to apply a function chain to your mosaic dataset to fill in areas between the pixels.



14. On the **Contents** pane, right-click the **BuildingRaster\Image** layer and choose **Zoom to Source Resolution** to better see the effects of the function chain.



15. With the same tool, apply the **2 Smooth** function, the **3 Smooth** function, and so on, until the buildings are filled in. To better see the effects of the tool, you might want to zoom closer or change **Basemap** to **Imagery** on the Map Tab to compare the buildings. You may also want to view different areas of the map to find smoothing level with the best overall result.
16. Return to the Catalog pane. Double-click **4) Extract Draft Building Footprint Polygons**.
17. Set the tool parameters as follows:
    - **Input raster:** Click the dropdown and select **BuildingRaster\Image** (this is the raster with your smoothing function applied).
    - **Output polygon features**: Set to ***DraftPolygons*** (in the ClassifiedBuildingMosaics.gdb created earlier)
18. Click **Run** to generate polygons from the raster. This tool uses the **Raster To Polygon** tool in the background with the Simplify option turned off.



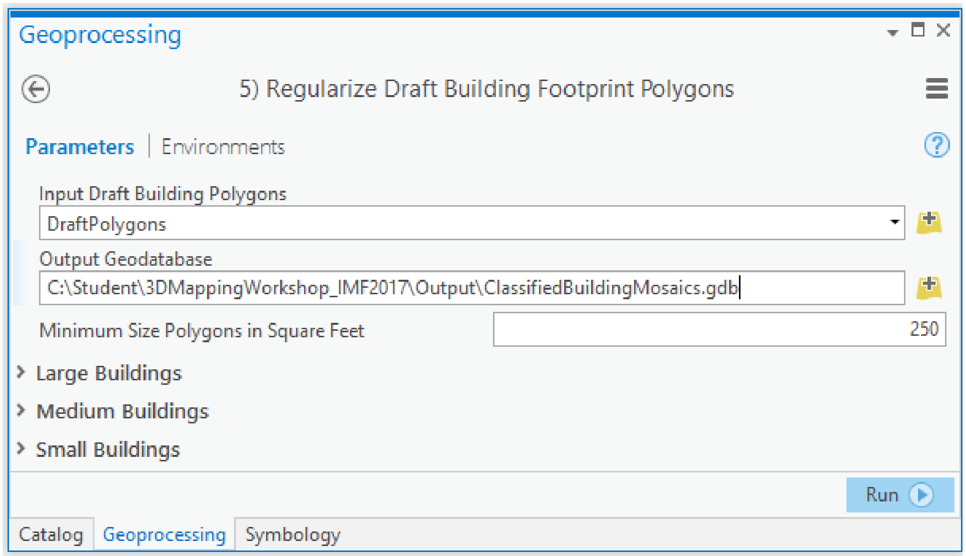
<u>Note:</u> If you have good Parcel data that lines up well with your **DraftPolygons**, you can run the Intersect Tool at this point between the **DraftPolygons** and Parcel features. This will often break up buildings joined together that are very close and break up vegetation along parcel edges. Use the output of this as input to the next tool (ignore for this exercise).

19. Return to the Catalog pane. Double-click **5) Regularize Draft Building Footprint Polygons**.

<u>Note</u>: The **Regularize Draft Building Footprint Polygons** tool is a complex model that divides the polygons into Small, Medium and Large polygons to process differently. It also finds possible Circle Buildings (tanks, for the majority). The **Minimum Size Polygons in Square Feet** parameter is pre-set to 250, which is equivalent to 23 square meters. This is roughly a 15ft x 15ft building. If you had lidar that could support smaller buildings, you could set a lower Minimum Size. There are advanced settings for Large, Medium and Small Buildings, but usually the preset defaults are preferred.

20. Set the tool parameters as follows:
    - **Input**: Should already be set to **DraftPolygons**
    - **Output Geodatabase**: Click the browse button and select **ClassifiedBuildingMosaics.gdb**
    - Leave all the other defaults

21. Click **Run** to clean up the polygons. (This might take a couple minutes.)



22. When complete, open the Catalog pane and expand **Folders > 3DMappingWorkshop_IMF2017 > Output > ClassifiedBuildingMosaics.gdb**. Right-click the **ClassifiedBuildingMosaics.gdb** and click **Refresh**.
23. Right-click each of the three layers (**Building_generalized**, **Buildings**, **CircleBuildings**) and select **Add To Current Map.**
24. For this exercise, you will be using only **Building_generalized,** so turn off the **Buildings** and **CircleBuildings**.

    Note: In normal production, you would review **CircleBuildings** to find ones that are real and delete others. Then a selection by location would be used to select and then delete **Building_generalized** that are coincident with **CircleBuildings**.

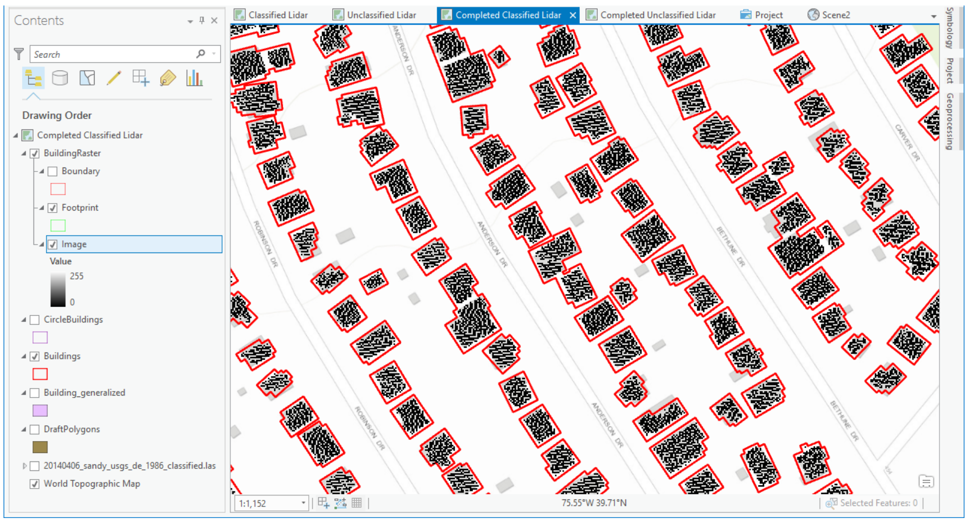
25. In the Contents pane, click the symbol for **Building_generalized** to open it in the Symbology pane.
26. On the Symbology pane, click **Properties**. Set the Appearance parameters as follows:
    - **Color:** Click the dropdown and select **No color**
    - **Outline color**: Click the dropdown and select **red**
    - **Outline width:** Increase to **2**.
27. Click **Apply** to symbolize building footprints extracted from classified lidar.

Part 2:

You have completed the process for extracting building footprints from lidar, and you have added the results to the map. Now you will examine the results and check for accuracy.

First, compare your results to the initial buildings raster, before you smoothed and regularized the results.

1. Rerun **3) Replace Mosaic Dataset Raster Function Template** on the **BuildingRaster** mosaic dataset, set to **0 No Smoothing.** The result will show the mosaic dataset before fill.
2. On the Map tab, change the Basemap to **Topographic** and if needed, turn off the **DraftPolygons** layer.
3. Zoom in to compare the mosaic dataset buildings (**BuildingRaster**) to the generalized buildings layer (Building_generalized).

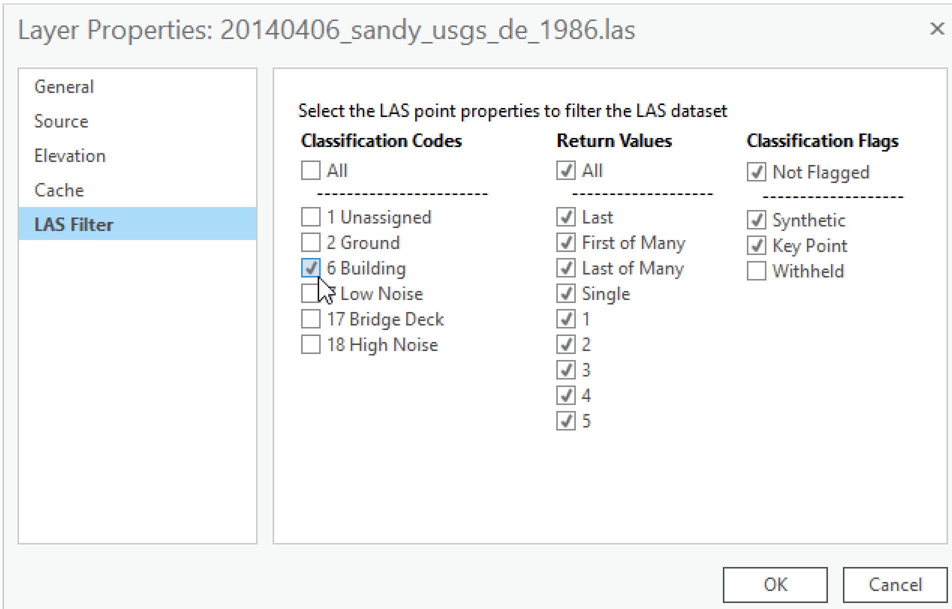


Second, check your results against aerial imagery.

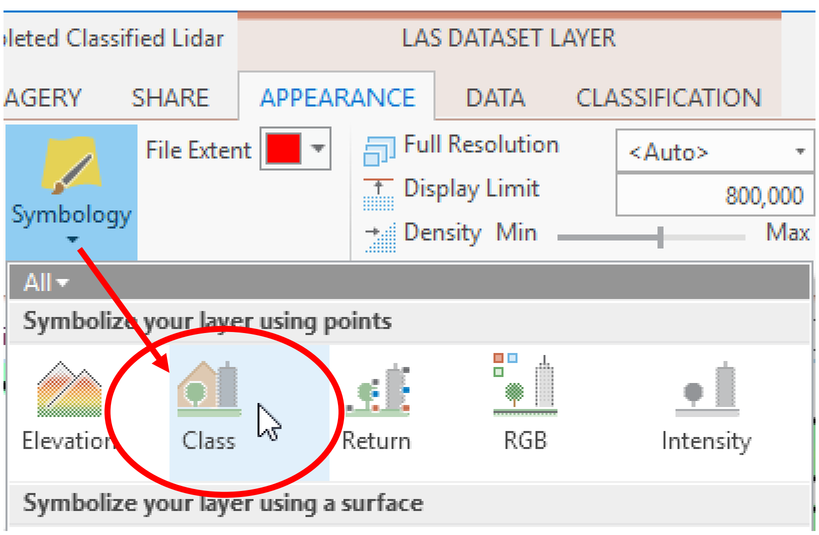
4. On the Map tab, change the Basemap to **Imagery**.
5. Turn off the **BuildingRaster** layer. Zoom in to compare the red footprints to the images of the buildings.

Third, compare the results to the original lidar data that is filtered just for buildings.

6. Double-click the .las layer (**20140406_sandy_usgs_de_1986.las**) in the Contents pane to open its **Layer Properties**.
7. Click the **LAS Filter** tab to the left. At the right, under Classification Codes, clear (uncheck) the **All** checkbox, then turn on **6 Building**.

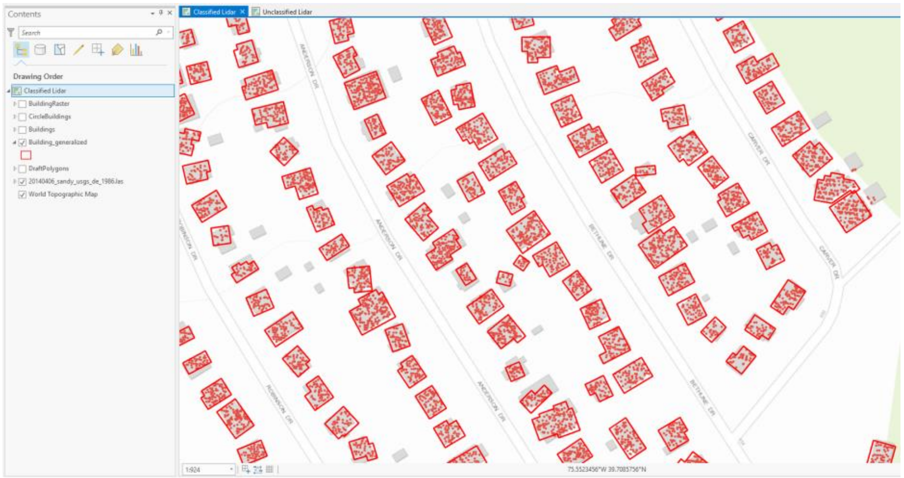


8. Click **OK** on **Layer Properties**.
9. On the Contents pane, turn on the .las layer and select it.
10. On the ribbon, click the **Appearance** tab. Click the **Symbology** dropdown, and select **Class.**



11. Change the line symbol color of **Buildings** to Mars Red.
12. On the Map tab, change the Basemap to **Topographic**.

Your display should look something like this:



These three comparisons should give you a general sense of how successful your building footprint extraction from classified lidar was.

Exercise 2: Extracting Building Footprints from Unclassified Lidar

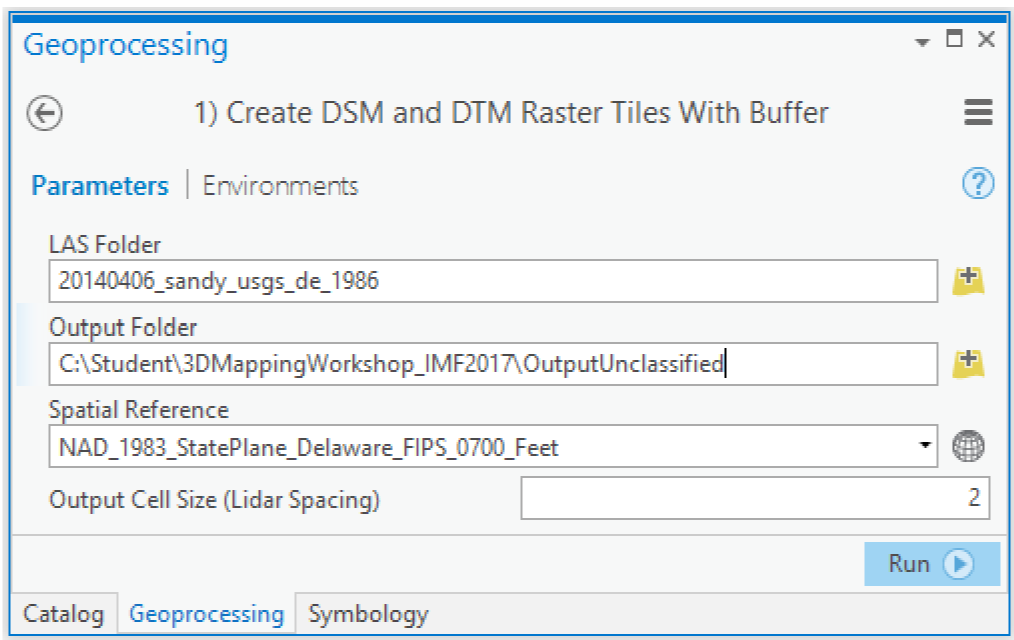
The idea for this extraction came from Dr. Thomas Pingel's work with bonemapping using shaded slope maps (check out an example bonemap image and the bonemap-matlab GitHub repo). In his images, the shaded slope map he calls a bonemap uses a sort of texture analysis that causes the trees to be much darker. He did not use it for extraction, but for better visualization of lidar. Cook County, IL, has a bonemap he produced on their open services.

By creating a bonemap using hillshade combined from different directions at a high altitude with areas below a certain height removed, it's possible to extract good building footprints from lidar that is not classified for buildings. Much of the existing lidar is not classified for buildings, which costs more to produce than ground-classified lidar. The bonemap approach also has promise for extracting different roof levels, or even air conditioners on top of roofs (as seen below).

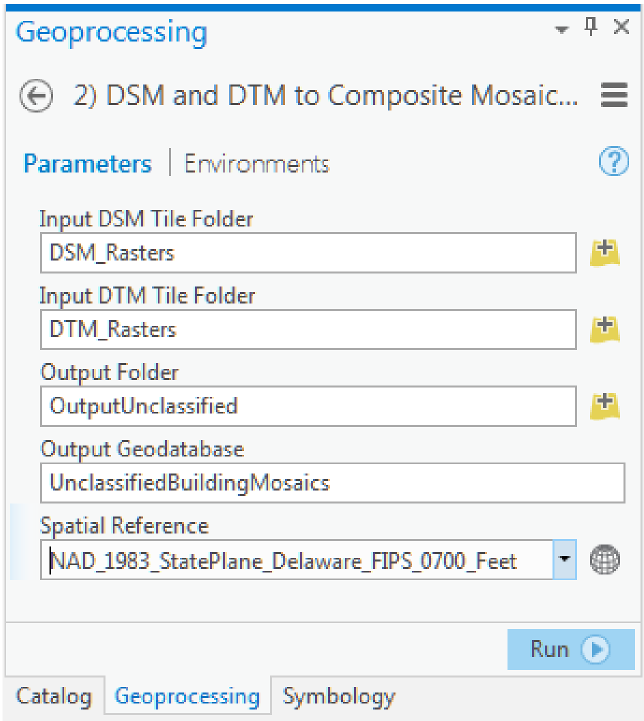
In this exercise, you will use this approach to extract building footprints from unclassified lidar. You will use the same lidar data as in the first exercise, but you will not use the lidar classifications in your analysis.

Part 1:

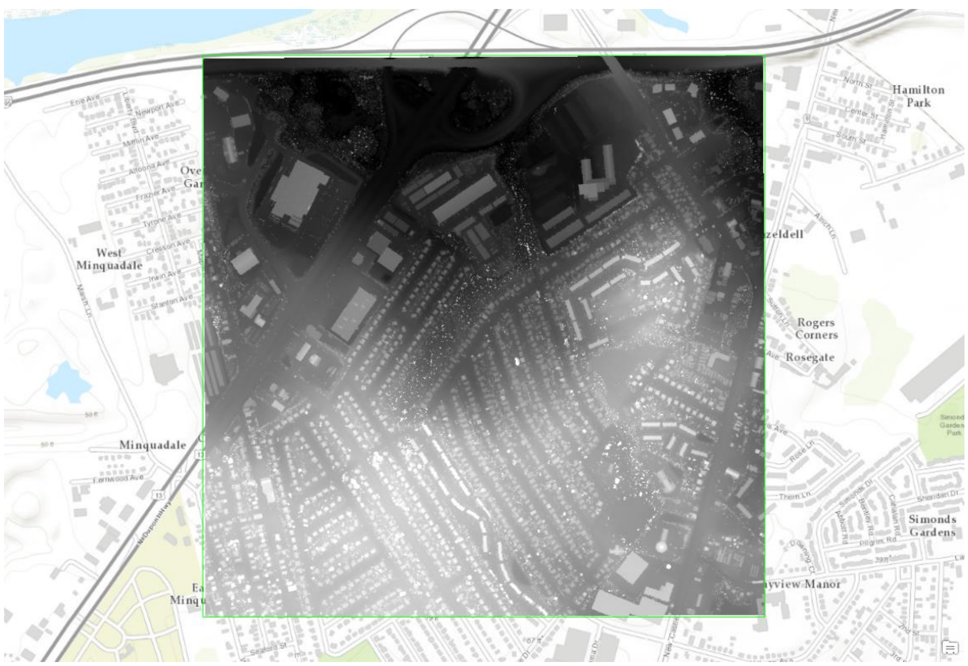
1. Activate the **Unclassified Lidar** Map by clicking on its title.
2. Remove the **BuildingRaster** layer and turn off the **20140406_sandy_usgs_de_1986.las** layer.
3. In the Catalog pane, expand the **ExtractBuildingFootprintsFromLidarUnclassifiedForBuildings_6_2_2017** toolbox and collapse the other one.
4. Double-click **1) Create DSM and DTM Raster Tiles With Buffer.**
5. Set the tool parameters as follows:
   - **LAS Folder**: Click the browse button, select **20140406_sandy_usgs_de_1986** (in the 3DMappingWorkshop_IMF2017 folder), then click **OK**
   - **Output Folder:** Enter **OutputUnclassified**
   - **Spatial Reference:** Use the dropdown to select **Current Map [Unclassified Lidar]**
   - **Output Cell Size (Lidar Spacing): 2**
6. Click **Run** to generate Digital Surface Model (DSM) and Digital Terrain Model (DTM) raster tiles derived from unclassified lidar data.



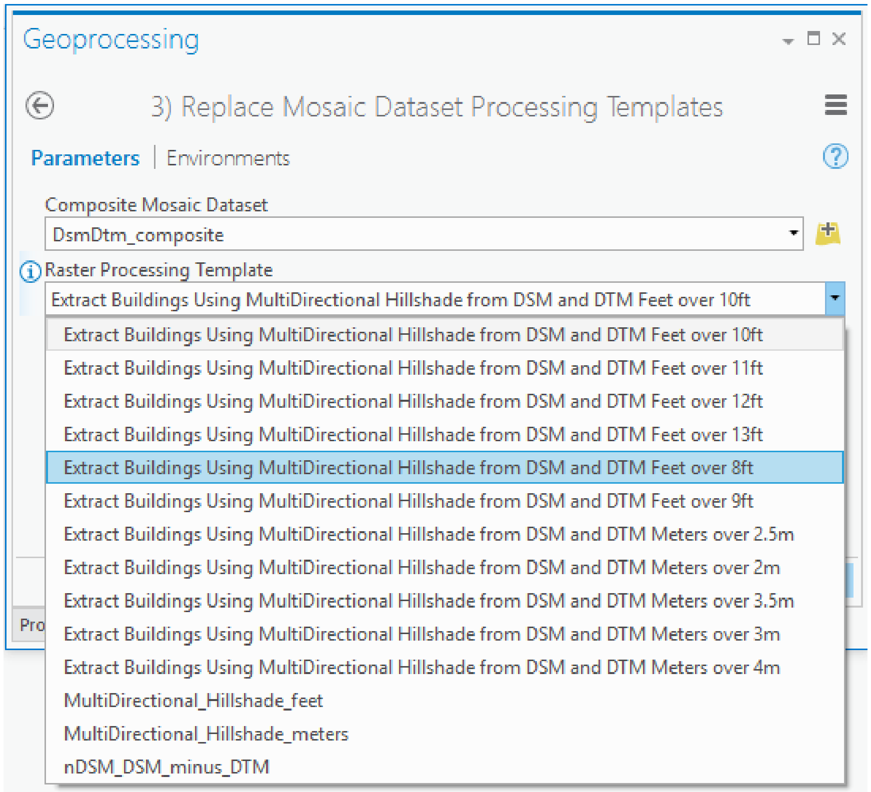
7. In the Catalog pane, double click **2) DSM and DTM to Composite Mosaic Dataset**. This tool creates a mosaic dataset with both the DTM and DSM rasters and adds them to the display.
8. Set the tool parameters as follows:
   - **Input DSM Tile Folder**: Click the browse button, navigate to **OutputUnclassified > DSM_Rasters**, then click **OK**
   - **Input DTM Tile Folder:** Should auto-fill with **DTM_Rasters** (If not, click the browse button, navigate to **OutputUnclassified > DTM_Rasters**, then click **OK**)
   - **Output Folder:** Should auto-fill with **OutputUnclassified** (If not, click the browse button, navigate to **OutputUnclassified**, then click **OK**)
   - **Output Geodatabase**: **UnclassifiedBuildingMosaics**
   - **Spatial Reference:** Use the dropdown to select **Current Map [Unclassified Lidar]**



9. Click **Run**. The output should look like this:



10. In the Catalog pane, double click **3) Replace Mosaic Dataset Raster Function Templates**.
11. Set the tool parameters as follows:
    – **Composite Mosaic Dataset:** use the dropdown to select **DsmDtm_composite**
    – **Raster Processing Template:** select the one that ends with ‘**over 8ft’**



12. **Run** the tool to apply a function chain to your mosaic dataset that extracts possible buildings from your DTM and DSM based on height.

    Note: The **Raster Processing Template** parameter has many options, allowing you to select the minimum height at which building are detected. In general, try different options (starting with 8ft) to determine the best option to accurately detect buildings in your data. In residential areas where single story buildings are, it's best to set it low (8 foot or so). In areas with just taller buildings, try to use a higher height (like 13 foot or 4 meters) to minimize the trees more. Some trees will still come in. An additional step sometimes that can be done to remove trees is to do an NDVI (from NAIP imagery) and using your output Draft Polygons as input to Zonal Statistics to add the NDVI mean value to the buildings. You can then select by smaller sizes and NDVI values to find these to delete. We will not cover that in this exercise. Also in areas where you have loading docks where semi-trailers are next to buildings, setting a height above the semi-trucks will remove the features from the buildings.

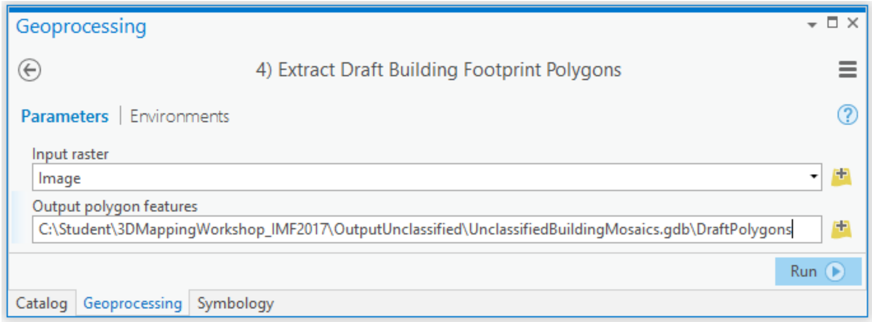
13. Go to **Map tab > Bookmarks > Oakwood Ct.** to see these buildings:

Optional: To see the bonemap that is behind the extraction, run the tool using the **MultiDirectional Hillshade_feet** Raster Processing Template. When the tool completes, go to the Appearance tab and check on DRA to show the multidirectional hillshade properly.

You cannot use this for the next tool, so re-run the tool with the 8ft or 10ft option before moving on.

14. From the Catalog pane, double-click **4) Extract Draft Building Footprint Polygons**.
15. Set the tool parameters as follows:
    - **Input raster:** Use the dropdown and select **DsmDtm_composite\Image**
    - **Output polygon features:** Set to ***DraftPolygons*** (in the UnclassifiedBuildingMosaics.gdb created earlier)

16. Click **Run**. This tool uses the **Raster to Polygon** tool with the Simplify option turned off. Most small polygons will be eliminated with the next tool.



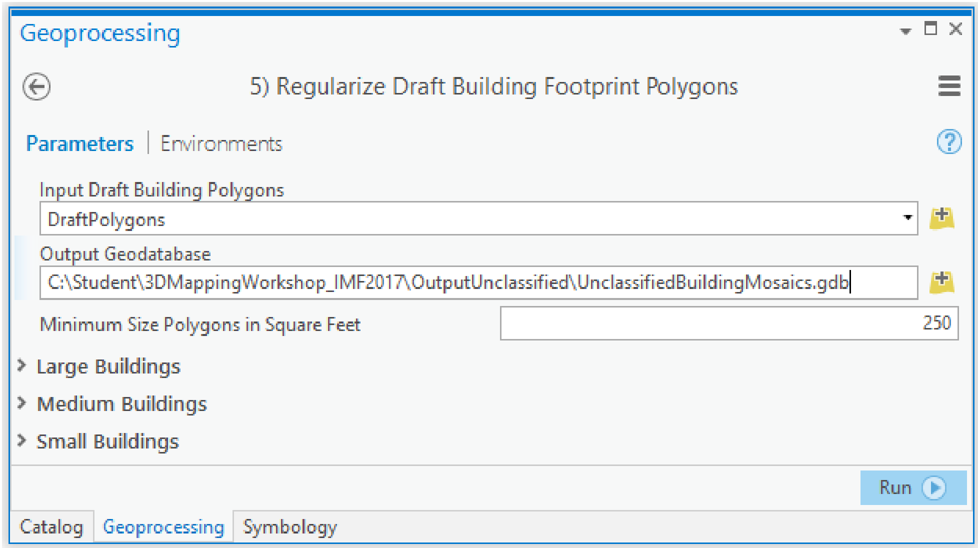
<u>Note:</u> If you have good Parcel data that lines up well with your **DraftPolygons**, you can run the Intersect Tool at this point between the **DraftPolygons** and Parcel features. This will often break up buildings joined together that are very close and break up vegetation along parcel edges. Use the output of this as input to the next tool (ignore for this exercise).

17. Select the **DraftPolygons** layer in the Contents pane. In the Symbology pane under Properties, change the symbology of DraftPolygons to have a **red outline** and **no fill** color.

18. From the Catalog pane, double click **5) Regularize Draft Building Footprint Polygons**.
19. Set the tool parameters as follows:
    - **Input Draft Building Polygons**: Should already be set to **DraftPolygons**
    - **Output Geodatabase**: Browse to and select **UnclassifiedBuildingMosaics.gdb** (in the OutputUnclassified folder)
    - **Minimum Size Polygons in Square Feet**: **250**

    <u>Note</u>: This tool uses a complex model that divides the polygons in Small, Medium and Large polygons to process differently. It also finds possible Circle Buildings (tanks, mostly). The **Minimum Size Polygons in Square Feet** is pre-set to 250, which is equivalent to roughly a 15ft x 15ft building. If your lidar can support smaller buildings, set it lower. There are advanced settings for Large, Medium and Small Buildings. Usually, the preset defaults are preferred.

20. **Run** the tool to clean up your building footprint polygons.



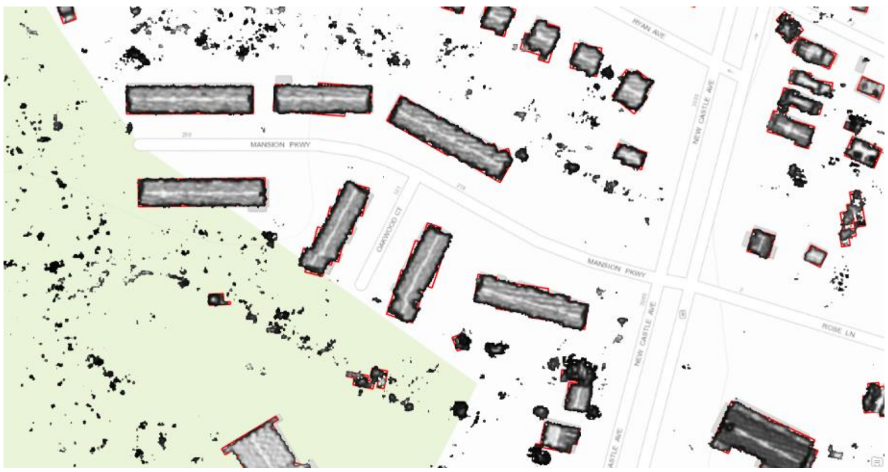
21. When complete, open the Catalog pane and expand **Folders > 3DMappingWorkshop_IMF2017 > UnclassifiedBuildingMosaics.gdb**. Right click the geodatabase and select **Refresh**.
22. Add the **Building_generalized** to the map (no circles are found in this area).
23. In the **Contents** pane, turn off **DraftPolygons** and **DsmDtm_composite**
24. Click the symbol for **Building_generalized** to open it in the **Symbology** pane.
25. On **Symbology** pane, click **Properties**.
    – Under **Appearance**, click the dropdown for **Color** and select **No color**.
    – Change the **Outline color** to red
    – Increase **Outline width** to **2**
26. Click **Apply**.

Part 2:

You have completed the process to extract building footprints from unclassified lidar, and you have added the results to the map. Now you will examine the results and check for accuracy.

First, compare the footprints to the buildings visible in the raster generated from the unclassified lidar.

1. Rerun the **3) Replace Mosaic Dataset Raster Function Template**, set to the **MultiDirectional Hillshade_feet**, to check against the building footprints.
2. With the mosaic dataset selected in the **Contents** pane, open the **Appearance** tab and click on **DRA** to better visualize the data.

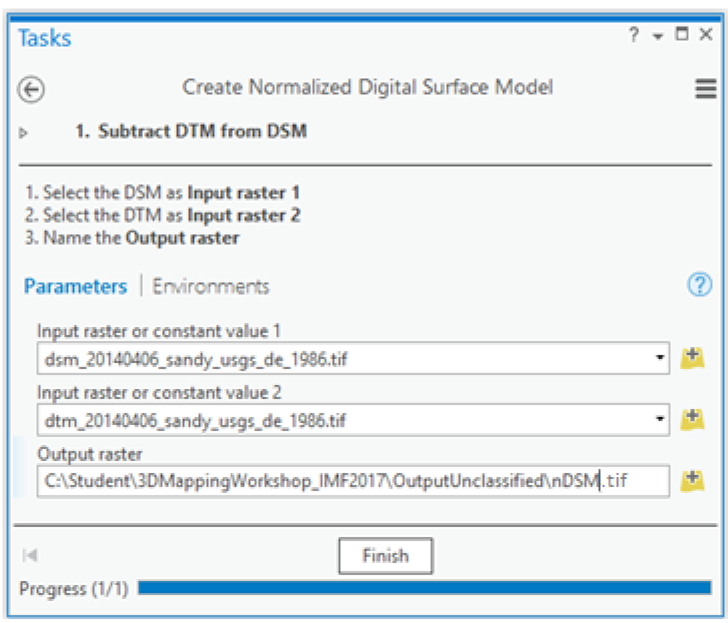


Second, compare the footprints to aerial imagery.

3. In Contents, turn off **DsmDtm_composite**.
4. From the Map tab, change the **Basemap** to **Imagery**. Zoom in to see how well the footprints align with the imagery.

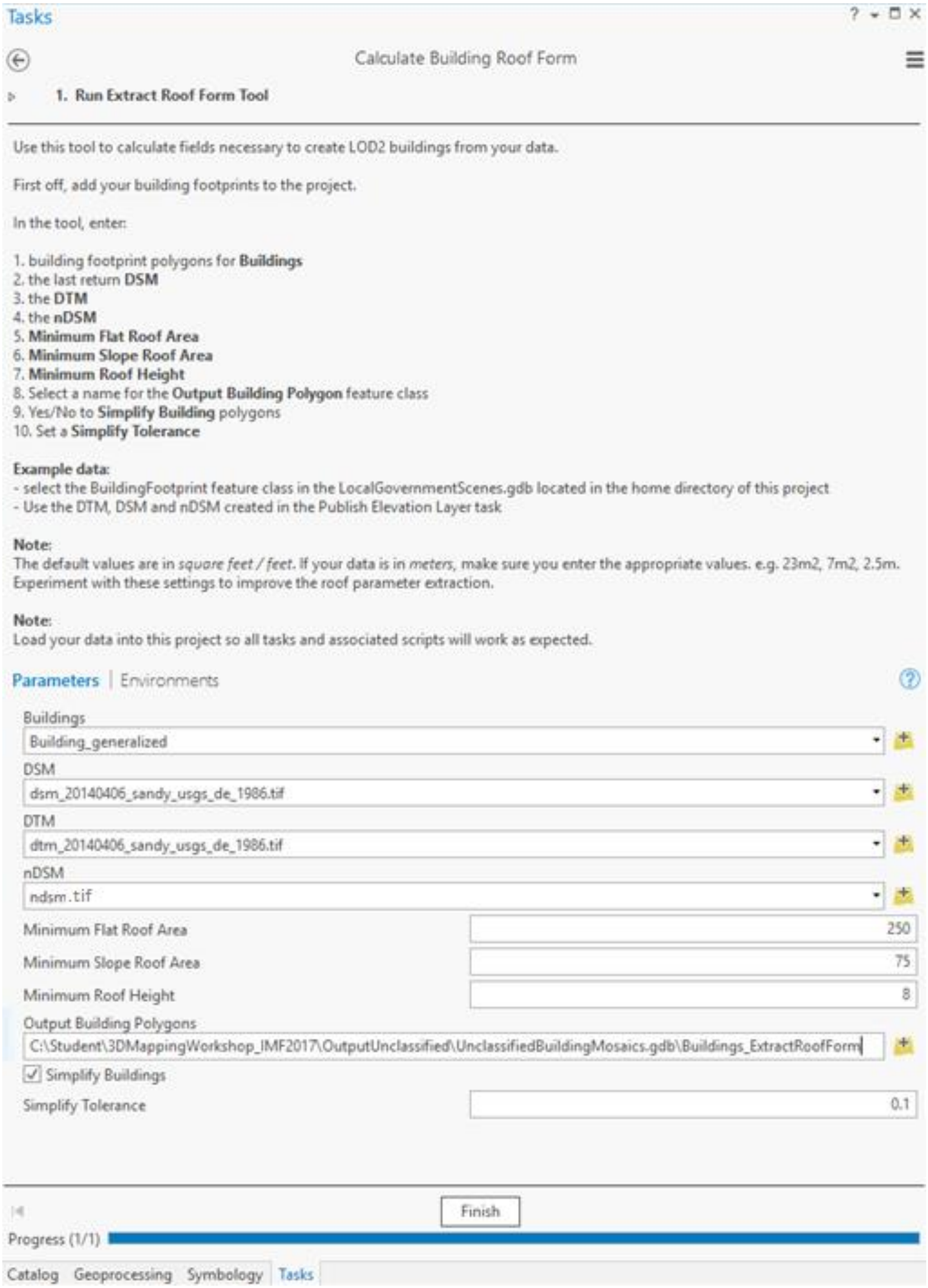
Exercise 3: Extracting Roof Forms

1. Double-click the **…\LocalGovernmentBasemaps3d\MapsandGeodatabase\SchematicLocalGovernmentScene.aprx** to open it. (Or, if you have ArcGIS Pro open already, click the Project tab on the ribbon, click **Open**, click **Browse** then select this project and click **OK**.)
2. Add data generated in the previous exercise to the Scene:
   - **OutputUnclassified\UnclassifiedBuildings.gdb\Building_generalized**
   - **OutputUnclassified\DSM_Rasters\dsm_20140406_sandy_usgs_de_1986.tif**
   - **OutputUnclassified\DTM_Rasters\dtm_20140406_sandy_usgs_de_1986.tif**
3. On the Contents pane, right-click on **Building_generalized** and select **Zoom to layer**
4. On the Contents pane, turn off the DSM and DTM layers.
5. In the **Catalog** pane, expand **Tasks**. Double-click **1. Publish Elevation Layers**. This opens into the Tasks pane.
6. In the **Tasks** pane, expand **Create Elevation Layers from Lidar**.
7. Double-click the last task, **Create Normalized Digital Surface Model**. Follow the steps described in the Tasks pane:
   - **Input raster 1** and **Input raster 2:** Use dropdowns to set the DSM and DTM
   - **Output raster:** Click the Browse button, navigate to the folder that contains your DSM and DTM rasters (OutputUnclassified), and name the new raster ***nDSM.tif***, and click **Save**
   - Click **Finish** to complete the task.



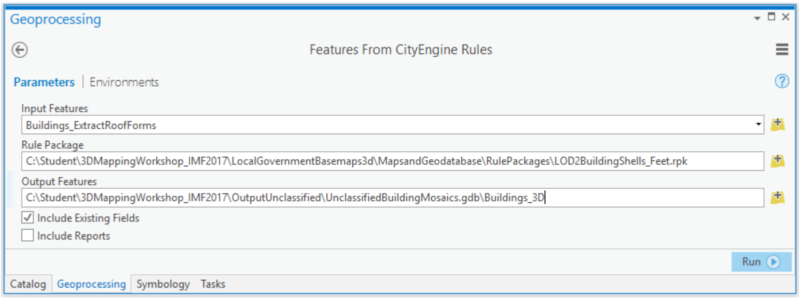
8. In the **Catalog** pane under Tasks, double-click **2. Publish LOD2 Buildings**.
9. On the **Tasks** pane, double-click **Calculate Building Roof Form**.

10. Follow the instructions listed in the steps, using the following parameters:
    - **Buildings**: Click the dropdown and select **Building_generalized**
    - **DSM**, **DTM** and **nDSM:** Use the dropdowns to select corresponding files.
    - **Output Building Polygons**: Set to **Buildings_ExtractRoofForm** (in OutputUnclassified\UnclassifiedBuildings.gdb)
    - Change the **Simplify Tolerance** to **0.01**
11. Click **Finish.**
    Note**:** This takes about 4 minutes to run on one lidar tile.

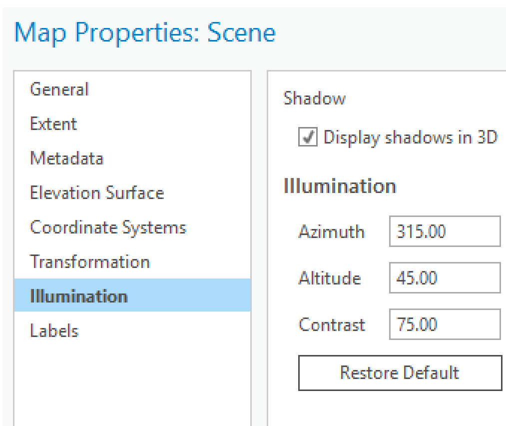


12. In the **Geoprocessing** pane, click the back arrow, type ***Features from*** in the Search box, and then hit the Enter key.
13. Click the **Features From CityEngine Rules** tool to open it.
    - **Input Features**: Select **Buildings_ExtractRoofForm**
    - **Rule Package**: Click the Browse button to navigate into …\LocalGovernmentBasemaps3D\MapsandGeodatabase\RulePackages**,** select **LOD2BuildingShells_Feet.rpk**, and click **Open**.
    - **Output Features**: Set to **Buildings_3D** (in OutputUnclassified\UnclassifiedBuildings.gdb)

14. **Run** the tool.



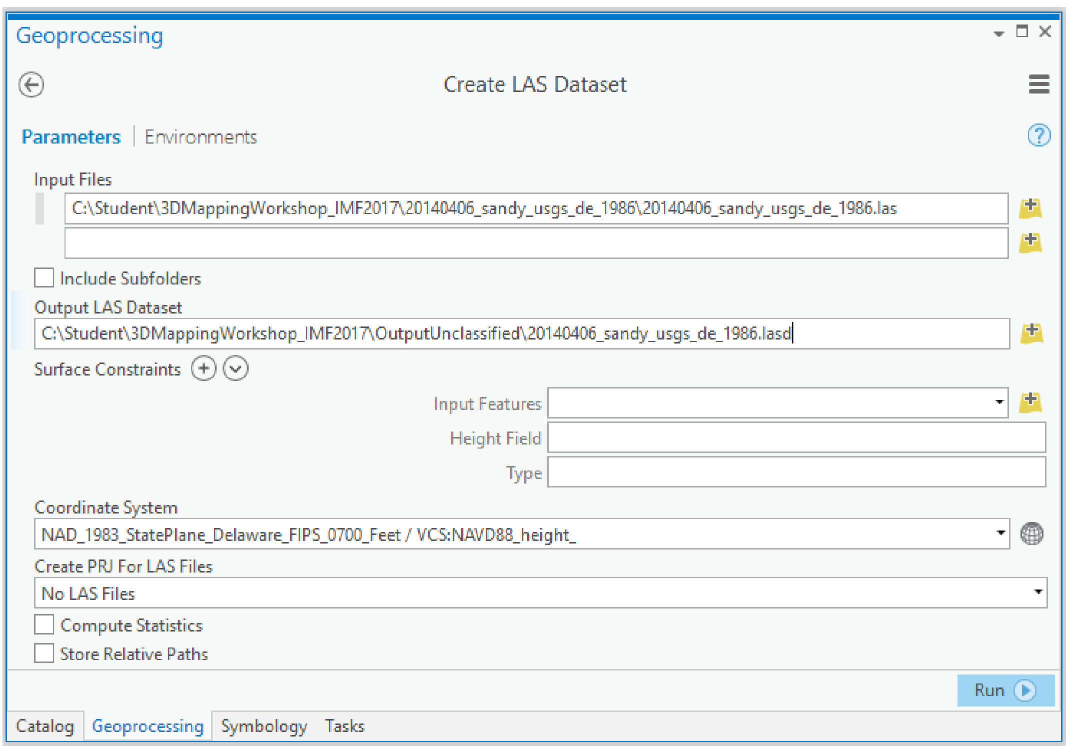
15. On the **Contents** pane, double-click the **Scene** name to open the properties.
16. Select the **Illumination** tab.
    - **Display shadows in 3D:** Check on
    - **Altitude:** Change to **45**
17. Click **OK.**



18. Turn off all 2D layers, change Basemap to **Imagery** (if not already), and navigate around the scene to check the 3D buildings.
19. Turn buildings off and on to compare the results with the imagery (You can use the arrow and ring on the bottom right of the scene to navigate to a straight-down view).

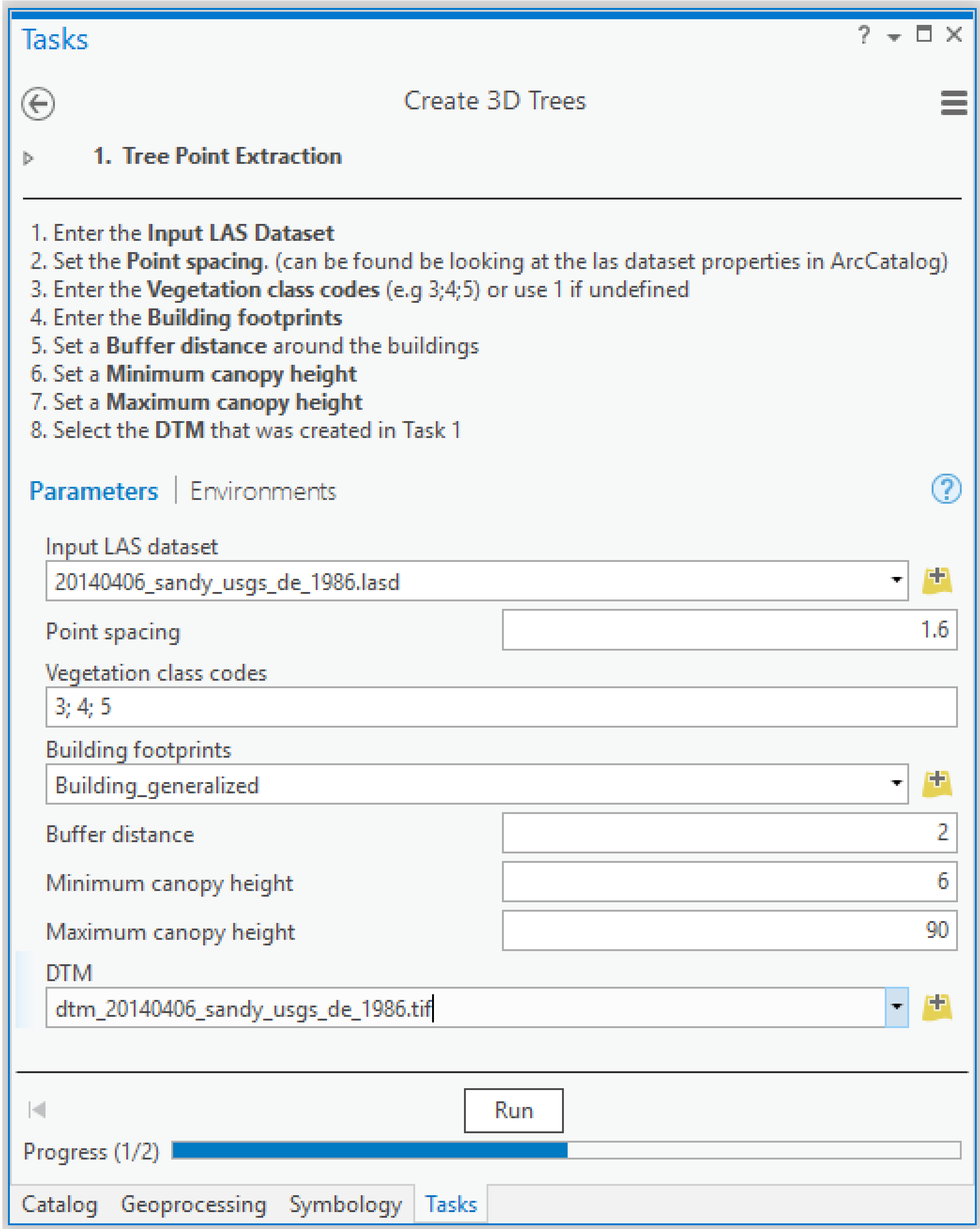
Exercise 4: Create 3D Trees

1. If you did not complete Exercise 3, double-click the **…\LocalGovernmentBasemaps3d\MapsandGeodatabase\SchematicLocalGovernmentScene.aprx** to open it.
2. If needed, add the following data generated in Exercise 2 and Exercise 3 (Map tab > Add Data):
   - **OutputUnclassified\UnclassifiedBuildings.gdb\Buildings_3D**
   - **OutputUnclassified\UnclassifiedBuildings.gdb\Building_generalized**
   - **OutputUnclassified\DTM_Rasters\dtm_20140406_sandy_usgs_de_1986.tif**
3. In the **Contents** pane, right-click on the **Building_generalized** layer and select **Zoom to layer**.
4. On the Analysis tab, select Tools. Search for and click the **Create LAS Dataset** tool to open it.
   - **Input Files**: Navigate to 3DMappingWorkshop_IMF2017\20140406_sandy_usgs_de_1986 and select **20140406_sandy_usgs_de_1986.las**
   - **Output LAS Dataset:** Set to **20140406_sandy_usgs_de_1986.lasd** (in 3DMappingWorkshop_IMF2017\OutputUnclassified)
5. Click **Run.**

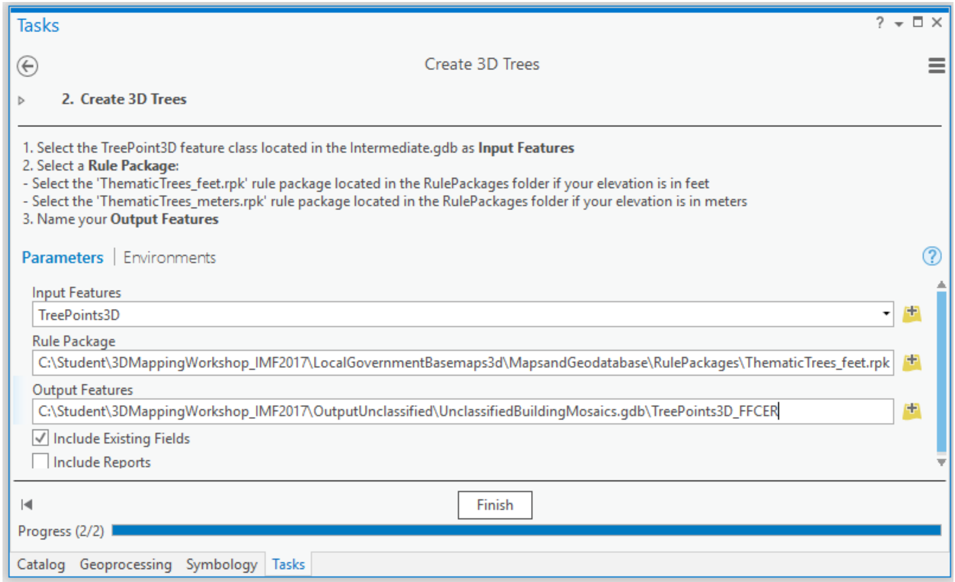


6. In the **Catalog** pane, expand **Tasks**. Double-click the third task, **Publish 3D Trees**. This opens into the Tasks pane.
7. In the **Tasks** pane, double-click **Create 3D Trees** to open **Step #1 (Tree Point Extraction)**.
   - **Input LAS dataset**: Use the dropdown to select **20140406_sandy_usgs_de_1986.lasd**
   - **Point spacing**: Enter **1.6**
   - **Vegetation class codes:** Enter **3; 4; 5**
   - **Building Footprints:** Use the dropdown to select **Building_generalized**
   - **DTM**: Use the dropdown to select **dtm_20140406_sandy_usgs_de_1986.tif**

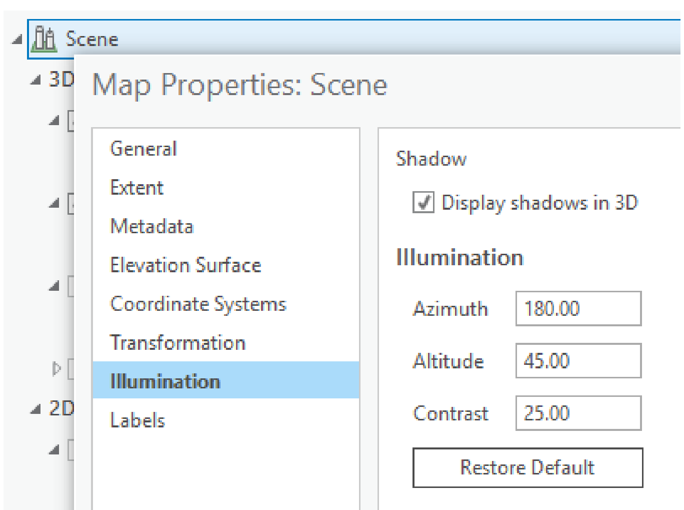
8. Click **Run**. (<u>Note</u>**:** this takes about 2 minutes to run on one lidar tile.)



9. Once the processing has finished, **Step #2 (Create 3D Trees)** will be displayed.
   - **Input Features**: Use the dropdown to select **TreePoints3D**
   - **Rule Package**: Click the browse button and select …\ LocalGovernmentBasemaps3d\MapsandGeodatabase\RulePackages **\ThematicTrees_feet.rpk**
   - **Output Features**: Accept the default **TreePoints3D_FFCER**
10. Click **Finish** to create 3D trees. (<u>Note</u>**:** this takes about 30 seconds to run on one lidar tile.)



11. On the **Contents** pane, turn off all the layers except **Buildings_3D** and **TreePoints3D_FFCER**.
12. If necessary, change the Basemap to **Imagery**
13. On the **Contents** pane, double-click the **Scene** name to open the properties
14. Select the **Illumination** tab. Change the following parameters:
    - **Display shadows in 3D**: Check on
    - **Azimuth:** to **180**
    - **Altitude:** Change to **45**
    - **Contrast:** Change to **25**
15. Click **OK** to visualize your results.



16. Navigate around the scene to check the results, which should look like this:


Scene

