

How-To Guide: Processing Multiple LOMAs using LiDAR



COLORADO
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Conservation Board
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This How-To guide describes the simple Geographic Information Systems (GIS) analysis process needed to prepare the supporting data for a large-scale Letter of Map Amendment (LOMA) using LiDAR for multiple structures or areas of a community. The area of interest could be as small as a cul-de-sac on a portion of a stream or as large as an entire town with multiple streams. This Guide was created in compliance with Section 5.0 of the MT-1 Technical Guidance document; https://www.fema.gov/media-library-data/1520966727494-8c05ecc18e141449aa79665641bd9fe3/MT1_Technical_Guidance_Feb_2018.pdf. **Note: LiDAR LOMAs cannot be processed based on AO, AH, A99, V, VE, and V1-V30 Zones or regulatory Floodways, nor for buildings with a basement or built on fill and can't supersede LOMAs with certified elevation data (Section 5.1 of MT-1 Technical Guidance). Structures in these flood hazard areas or with these characteristics would need to be processed individually using a different Letter of Map Change (LOMC) method.**

01 Required Software & Input Data

The following items are needed to prepare the supporting data for a LOMA in a Zone AE flood hazard area:

1. **ArcGIS software with an active license and with the Spatial Analyst and 3D Analyst extensions licensed and activated.**
2. **Building Footprints Dataset (vector polygon format)**
 - Data should be obtained from local community or county if possible.
 - If data is not available from a local entity, then it should be digitized from orthophotography. The digitized footprints should then be compared to the terrain data to verify location.
 - Building footprint data can also be obtained from the Microsoft Building Footprint dataset here: <https://github.com/microsoft/USBuildingFootprints> which is also available through ArcGIS' Add Online Data tool.
3. **Terrain Data (Digital Elevation Model (DEM) or Contours)** that meets Quality Level 3¹ as defined by the US Geological Survey (USGS) along with the associated metadata/report and a certification document from the terrain originator. This data is typically obtained at the local community, county, or state level. This data must be newer than what was used for the latest Flood Study.
4. **National Flood Hazard Layer (NFHL) Database (DB)**, which is available for download at the community, county, or state level from FEMA's Map Service Center (MSC) at <https://msc.fema.gov>.
 - Flood Hazard Areas (S_Fld_Haz_Ar)
 - Base Flood Elevations (S_BFE)
 - Cross Sections (S_XS)
 - Flood Insurance Study Report (FIS)
 - Profile Baseline (S_Profil_BasLn OR S_Wtr_Ln)**OR**, Download the **Non-Regulatory Products** if available (1% Annual Chance Water Surface Elevation [WSEL] Grid) from the MSC.

For Zone A streams, where there are no cross sections or Base Flood Elevations (BFEs) published on the FIRM, the user must research whether Cross Section, WSELs, or WSEL Grids are available from the NFHL, the MSC, or state, regional, and local agencies before proceeding with this Guide.

¹The USGS' LiDAR quality levels are defined in *Lidar Base Specification, Version 1.3*, February 2018, which can be downloaded here: <https://pubs.er.usgs.gov/publication/tm11B4>.

02 Creating Analysis Layers

This section describes how to extract the layers used to perform the analysis, identify the impacted buildings, and extract WSEL information from the effective data. In this section, you'll create the following data layers: LOMA_SFHA, LOMA_XS, LOMA_BFE, and LOMA_Structs.

Step 1. Start a new ArcGIS document and save with an appropriate name to your folder of choice.

This will be the Working Folder for this Guide. Set the map projection to match the terrain data. Review terrain source documentation to verify projection information.

Step 2. Extract Special Flood Hazard Areas (SFHA) from S_Fld_Haz_Ar

1. Load S_Fld_Haz_Ar from the NFHL DB into your ArcGIS document.
2. Right click on layer and go to 'Properties'.
3. In the Definition Query tab select Query Builder.
4. Enter SQL script:
 - a. If the LOMA project area is Zone AE, type "FLD_ZONE" = 'AE' and click OK.
 - b. If the LOMA project area is Zone A and there are cross sections type "FLD_ZONE" = 'A' and click OK.
 - c. If the LOMA project area is both Zone AE and A, type "FLD_ZONE" = 'AE' OR "FLD_ZONE" = 'A' and click OK.
5. Right click on the layer in the Table of Contents pane and select 'Data', then 'Export Data'.
6. Export 'All Features' using 'this layer's source data' for the coordinate system, select the Working Folder as the output location, and name appropriately. For this Guide, this layer will be called "LOMA_SFHA".
7. Press 'Yes' when asked if you want the data to be loaded into the map.

Step 3. Create SFHA for Project Area

1. Start Editing the LOMA_SFHA layer.
2. Use the Cut Polygon tool  to cut the LOMA_SFHA polygons to the LOMA project area.
3. Select polygons outside LOMA project area and delete.
4. Save edits and stop editing.

Step 4. Extract S_XS

1. Load S_XS from the NFHL DB or source data into your ArcGIS document.

2. Click the Selection tab and 'Select By Attributes.' Select S_XS and input query "WTR_NM" = 'Stream name being analyzed' and click OK.
3. If multiple streams "WTR_NM" = 'LOMA Area StreamA' OR "WTR_NM" = 'LOMA Area StreamB'
4. Right click on S_XS layer and go to 'Data', then 'Export Data'.
5. Export 'Selected Features' to the Working Folder using 'this layers' source data' for coordinate system and name appropriately. For this Guide this layer will be called LOMA_XS.

Step 5. Extract S_BFE

1. Load S_BFE from the NFHL DB or source data into your ArcGIS document.
2. Use the Select Tool  from the Tools Toolbar to select the BFEs within the LOMA project area.
3. Right click on S_BFE and go to 'Data', then 'Export Data'.
4. Export 'Selected Features' to the Working Folder using 'this layer's source data' for coordinate system and name appropriately. For this Guide this layer will be called LOMA_BFE.

Step 6. Select Buildings within SFHA and setup for Attribution

1. Load Building Footprints into your ArcGIS document. For the purposes of this document, this data will be named "Building_Footprint"
2. Click the Selection tab and click 'Select By Location'.
3. Select features from Target Layer = 'Building Footprint', Source Layer is LOMA_SFHA, and Spatial Selection Method for target layer feature = 'intersect the source layer feature'; click OK.
4. Right click on Building_Footprint layer and select 'Data', then 'Export Data'.
5. Export 'Selected Features' to the Working Folder using 'this layer's source data' for coordinate system and name appropriately. For this Guide, this layer will be called LOMA_Structs.
6. If a Floodway exists within the flood hazard area any structure partially or fully in the floodway should be removed from further analysis. To do this:
 - a. Click the Selection tab and select 'Select By Attributes' for the layer LOMA_SFHA, with query "ZONE_SUBTY" = 'Floodway' and click OK.

- b. Go to 'Select By Location' and use the same selection as Step 3 but click the 'Use selected Features' box below the Source Layer.
- c. Delete selected structures from LOMA_Structs.
7. Right click on the LOMA_Structs layer and select the Attribute Table.
8. Click  and select Add Field.
9. Add the following fields with the appropriate field type and precision as listed.
 - a. ID (Field Type = Short, Precision = Default) This field is the record number.
 - b. LAG (Field Type = Double, Precision = Default). This field is for the Lowest Adjacent Grade (LAG) elevation.
 - c. NEWLAG (Field Type = Double, Precision = Default). This field will subtract one or two feet from LAG based on the terrain data being used to meet MT-1 Guidance requirements.
 - d. WSEL (Field Type = Double, Precision = Default) This field is the Water Surface Elevation value.
 - e. BSMNT (Field Type = Text, Precision = Default). This field is a True/False logic statement to record if there is a basement present.
 - f. FILL (Field Type = Text, Precision = Default). This field is a True/False logic state to record whether the structure was elevated on fill.
 - g. Diff (Field Type = Double, Precision = Default). This field holds the calculated difference between the WSEL and NEWLAG.
 - h. Determ (Field Type = Text, Precision = Default). This text field holds the determination whether the NEWLAG is above or below WSEL.
10. Right click the ID Field and select Field Calculator and enter ID = [FID]+1. (You will get a warning that you are calculating values outside an edit session. Click Ok)

Step 7. Merge LOMA_SFHA Features.

1. Start editing LOMA_SFHA layer.
2. Select all polygons in the LOMA_SFHA layer.
3. Select Editor on Editor Toolbar and then select 'Merge'.
4. Select the top record, click OK, save edits and stop editing.

03 Build WSEL TIN

This section describes how to develop the WSEL Triangular Irregular Network (TIN) that will be used to determine the flood elevations for structures in the LOMA project area. *If you have the 1% Annual Chance WSEL Grid from FEMA's Non-Regulatory products for the project area, copy the grid into the Working Folder and skip to the Data Analysis section.*

1. Open ArcToolbox.
2. In 3D Analyst Tools, select 'Data Management', then select 'TIN', then open the 'Create TIN' tool.
3. For the Output TIN, select the Working Folder and name the TIN appropriately. For this Guide this layer will be called WSEL_TIN.
4. Coordinate System should be set to State Plane for the project area.
5. Using the Input Feature Class drop down, add:
 - a. LOMA_BFE (Height Field = Elev; SF Type = Hard_Line; Tag Field = default)
 - b. LOMA_XS (Height Field = WSEL_REG; SF Type = Hard_Line; Tag Field = default)
 - c. LOMA_SFHA (Height Field = <None>; SF Type = Hard_Clip; Tag Field = default)

If the created TIN does not cover the entire floodplain, there are not enough features in LOMA_XS and/or LOMA_BFE. These areas can be identified after generating an initial TIN and usually occur in areas of significant stream meandering. This step can be time consuming. The user should first verify using the profile and ground values extracted at structures that there is a possibility the structures could be removed. Use the stream profiles provided in the FIS to create interpolated LOMA_XS features to supplement what is in the NFHL or source data:

1. Load the S_Profil_BasIn or S_Wtr_Ln (if S_Profil_BasIn is not present) from the NFHL DB into your ArcGIS document.
2. Start editing the LOMA_XS layer.
3. On the profile, measure from a known point (cross section or bridge/culvert) to a desired WSEL on the 1% Annual Chance profile line.
4. Measure that same distance in ArcGIS along the corresponding S_Profil_BasIn feature.
5. Use the Create Feature tool to generate a new feature within the LOMA_XS layer. The interpolated XS should be drawn perpendicular to the flow of the stream and as a straight line.
6. Open the attribute table for the LOMA_XS layer.
7. Add the WSEL from the profile into the WSEL attribute.
8. Repeat from Steps 6 - 11 as many times as needed to close the gaps in the TIN.
9. Save Edits and stop editing. Repeat Steps 1-5 in the beginning of this section to rebuild the TIN.

04 Data Analysis – Extract WSEL from TIN

This section describes how to obtain WSEL values for the structures in the LOMA project area from TINs.

1. Make sure LOMA_Structs and the WSEL_TIN or 1% Annual Chance Flood WSEL Grid are loaded in your ArcGIS document.
2. Open ArcToolbox.
3. In 3D Analyst Tools, select 'Functional Surface', then open the 'Add Surface Information' tool.
4. Input Feature Class = LOMA_Structs; Input Surface = WSEL_TIN (This can also be the WSEL Grid if available); Output Property check 'Z-Max'; other options leave as default, click OK.
5. Open LOMA_Structs attribute table.
6. Run Field Calculator with expression: WSEL = Z_Max.
7. Right click on the Z_Max attribute and select delete.
8. Verify all features have WSEL values.
9. If there are any values without a WSEL value zoom to each structure and verify it overlaps the TIN. If not return to step 3 to expand the TIN to cover the floodplain.

If this method doesn't work for your data, see the Alternative Processing Option on the last page of this Guide!

05 Data Analysis – Extract LAG from DEM

This section describes how to obtain LAG values for the structures in the LOMA project area from DEMs. *If you only have contour data, see the Extract LAG from Contours task on the last page of this guide.*

1. Make sure the LOMA_Structs and the ground DEM (a raster or TIN of the terrain data) are loaded into your ArcGIS document.
2. Open ArcToolbox.
3. In 3D Analyst Tools, select 'Functional Surface', then open the 'Add Surface Information' tool.
4. Input Feature Class = LOMA_Structs
5. Input Surface = Ground DEM; Output Property check 'Z-Min'
6. Leave other options as default, click OK.
7. Right click on the LOMA_Structs layer and select Attribute Table.
8. Right click on the LAG attribute and select Field Calculator with expression: LAG = Z_Min.
9. Right click on the Z_Min attribute and delete.
10. Verify all features have values.
11. If there are any structures without a value zoom to each structure and verify the DEM covers the structure. Obtain additional terrain data as needed to cover area.
12. Right click on NEWLAG and select Field Calculator and enter NEWLAG = LAG - 2.

If this method doesn't work for your data, see the Alternative Processing Option on the last page of this Guide!

06 Calculate the Determination

This step describes how to make a determination of whether each identified building is eligible for a LOMA. At the end, you will know which are eligible for further refinement.

1. Open the attribute table for LOMA_Structs.
2. Use Field Calculator to find the elevation difference:
 - a. Diff = 'NEWLAG' - 'WSEL'Calculated values that are above zero (0) are above the 1% Annual Chance Flood WSEL. Values equal to or below zero (0) are below the 1% Annual Chance Flood WSEL.
3. Select the values above zero (0) by double clicking the Diff field to sort records and highlight all values >0; then Field Calculate the Determ Field as 'Above WSEL'.
4. Select the values equal to or below zero (0) by double clicking the Diff field to sort records and highlight all values ≤0; then Field Calculate the Determ Field as 'Below WSEL'.

07 Determine if a Basement is Present

Only structures without a basement that are determined to be above the LAG should be included in the LOMA application.

Option 1 If the Building Footprint data or local community assessor data include attributes regarding whether a basement is present, then populate the BSMNT attribute in LOMA_Structs with a True or False for the structures determined to be 'Above WSEL' based on those data.

Option 2 If basement information is not readily available, manual review will be needed to determine if any potential structures have a basement. It is best to work with a community representative or other person familiar with the types of structures typical to the area when evaluating each structure using online resources:

- Google Street View® can be used to identify if window wells or foundations vents are present, which would indicate a basement exists
- Zillow® or an alternative real estate website can be used to verify any structures that are not easily identifiable in Google Street View

Populate the BSMNT attribute in LOMA_Structs manually with True or False for each 'Above WSEL' structure based on the visual assessment.

08 Determine if the Structure was Elevated on Fill

Only structures that were not elevated on fill can be included in a LiDAR LOMA. Structures elevated on fill must be processed individually using another LOMC method.

Option 1 Work with a community representative to review building permit records for the structures.

Option 2 If permitting records are not readily available, review the terrain data for obvious signs of fill placement, such as closed contours around each structure.

Populate the FILL attribute in LOMA_Structs manually with True or False for each 'Above WSEL' structure

09 Finalizing the Dataset

Once all the structures have been evaluated, select the ones that will be submitted for a LOMA and create a new shapefile for use in preparing the LOMA submittal. Use the resulting file to prepare a LiDAR LOMA submittal using the LiDAR LOMA Submittal How-To Guide available from ColoradoHazardMapping.com.

1. Right click on the LOMA_Structs layer and go to 'Properties'.
2. In the Definition Query tab select Query Builder.
3. Enter SQL script: "DETERM" = 'Above WSEL' AND "BSMNT" = 'FALSE' AND "FILL" = 'FALSE' and click OK.
4. Right click on LOMA_Structs in the Table of Contents pane and select 'Data', then 'Export Data'.
5. Export 'All Features' using 'this layer's source data' for coordinate system, select the Working Folder, and name appropriately. For this Guide, this layer will be called "LOMA_Structs_Final".

Alternative Methods and Additional Information

Data Analysis – Extract WSEL from TIN, Alternative Processing Option

This section describes an alternate method to obtain WSEL values for the structures in the LOMA project area from TINs.

1. Open ArcToolbox.
2. In Spatial Analyst Tools, select 'Zonal' and open the 'Zonal Statistics' tool.
 - a. Input Raster or feature zone data = LOMA_Structs
 - b. Zone Field = ID
 - c. Input Value raster = WSEL_TIN
 - d. Output raster = Select the Working Folder and name the output accordingly, making sure to specify a file extension (i.e. .tif). Avoid special characters and names longer than 11 characters. For this Guide, this layer will be called WSEL.tif.
 - e. Statistics type = 'MAXIMUM'
 - f. Click OK.
3. In 3D Analyst Tools, select 'Functional Surface' and open the 'Interpolate Shape' tool.
 - a. Input Surface = WSEL.tif
 - b. Input Feature Class = Struct_Pts
 - c. Output feature class = Export to Working Folder. For this Guide, the layer will be called Pts_WSEL.
 - d. Leave all other variables as default.
 - e. Click OK.
4. In Data Management Tools, select 'Features' and open the 'Add XY Coordinates' tool.
 - a. Input = Pts_WSEL, click OK.
5. Right click on LOMA_Structs, click 'Joins and Relates' and then click 'Join'.
 - a. Select 'Join attributes from a table' from the drop down.
 - b. Field 1 = ID; Field 2 = Pts_WSEL; Field 3 = ID
 - c. Select 'Keep all records' (default).
 - d. Click OK.
6. Start editing LOMA_Structs.
7. Open the LOMA_Structs attribute table, right click on WSEL and click Field Calculator. Enter WSEL = 'Z' (the 'Z' attribute from the joined Pts_WSEL attributes).
8. Save edits; stop editing.
9. Right click LOMA_Structs, click 'Joins and Relates' and then click 'Remove Joins' and 'Remove all joins'.
10. Verify all features have WSEL values.
11. If a structure does not have a value, zoom to the structure and verify the structure touches the grid. If the structure is not covered by the grid, verify that it is within the floodplain.

Data Analysis – Extract LAG from DEM, Alternative Processing Option

This section describes an alternate method to obtain LAG values for the structures in the LOMA project area from DEMs.

1. Open ArcToolbox.
2. In Spatial Analyst Tools, select 'Zonal', and open the 'Zonal Statistics' tool.
 - a. Input Raster or feature zone data = LOMA_Structs
 - b. Zone Field = ID
 - c. Input Value raster = Ground DEM
 - d. Output raster = Select the Working Folder and name the output accordingly, making sure to specify a file extension (i.e. .tif). Avoid special characters and names longer than 11 characters. For this Guide, this layer will be called LAG.tif.
 - e. Statistics type = 'MINIMUM'
 - f. Click OK.
3. In ArcToolbox, select Data Management Tools, select 'Features', and open the 'Feature to Point' tool.
 - a. Input Features = LOMA_Structs
 - b. Output Feature Class = Export point shapefile to Working Folder. For this Guide, this layer will be called Struct_Pts.
 - c. Check box 'Inside (optional)'
 - d. Click OK.
4. In ArcToolbox, select 3D Analyst Tools, select 'Functional Surface' and open the 'Interpolate Shape' tool.
 - a. Input Surface = LAG.tif
 - b. Input Feature Class = Struct_Pts
 - c. Output feature class = Export to Working Folder. For this Guide, the layer will be called Pts_LAG.
 - d. Leave all other variables as default.
 - e. Click OK.
5. In Data Management Tools, select 'Features', and open the 'Add XY Coordinates' tool.
 - a. Input = Pts_LAG, click OK.
6. Right click on LOMA_Structs layer, click 'Joins and Relates' and then click 'Join'.
 - a. Select 'Join attributes from a table' from the drop down.
 - b. Field 1 = ID; Field 2 = Pts_LAG; Field 3 = ID
 - c. Select 'Keep all records' (default).
 - d. Click OK.
7. Start editing LOMA_Structs.
8. Open LOMA_Structs attribute table right click on LAG and click field calculator. Enter LAG = 'Z' (the 'Z' attribute from the joined Pts_LAG attributes).
9. Save edits; stop editing.
10. Right click LOMA_Structs, click 'Joins and Relates' and then click 'Remove Joins' and 'Remove all joins'.
11. Verify all features have values.
12. If a feature does not have a value, zoom to the structure and verify the structure touches the DEM. If it does not, then obtain more terrain information to cover the project area.
13. Field Calculate NEWLAG = LAG - 2.

Data Analysis– Extract LAG from Contours

This section describes how to obtain LAG values for the structures in the LOMA project area from contours.

1. Load Contour data and LOMA_Structs into your map ArcGIS document.
2. Right click on LOMA_Structs, select 'Join and Relates,', and then select 'Join'.
 - a. For What do you want to join to this layer, select 'Join data from another layer based on spatial location' from the drop down.
 - b. For Item 1, select Contour data as file.
 - c. For Item 2, select the default 'Each polygon will be given a summary of the numeric attributes of the lines that intersect it', Select the Minimum check box.
3. For Item 3, export the resulting shapefile to the Working Folder, name accordingly, then click OK. For this Guide, the layer will be called Cont_Output.
4. In the newly made shapefile, right click and open the attribute and verify the all records in the attribute Cont_Output have an elevation value. If any records are zero (0), then each one of those will need to be manually reviewed to determine the nearest, lowest contour and elevation at that structure.
5. Once all structures have a contour value, right click on LOMA_Structs, select "Joins and Relates," then select 'Join'.
 - a. Select 'Join attributes from a table' from the drop down.
 - b. Field 1 = ID; Field 2 = Cont_Output; Field 3 = ID
 - c. Select 'Keep all records' (default).
 - d. Click OK.
6. Start editing LOMA_Structs.
7. Right click on LOMA_Structs and open the attribute table and right click on LAG and click on field calculator. Enter LAG = 'Z' (the flood elevation attribute from the joined Cont_Output attributes).
8. Save edits; stop editing.
9. Right click LOMA_Structs, click 'Joins and Relates' and then click 'Remove Joins' and 'Remove all joins'.
10. Right click on LOMA_Structs and open attribute table. Right click on NEWLAG and click on Field Calculator. Enter NEWLAG = LAG - 1.

Acronyms

BFE	Base Flood Elevation
DB	Database
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
GIS	Geographic Information Systems
LAG	Lowest Adjacent Grade
LOMA	Letter of Map Amendment
LOMC	Letter of Map Change
MSC	Map Service Center
NFHL	National Flood Hazard Layer
SFHA	Special Flood Hazard Area
TIN	Triangular Irregular Network
USGS	United States Geological Survey
WSEL	Water surface elevation

Questions? Comments?

For any questions or comments on this How-To Guide please contact:

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For assistance with LiDAR LOMA within the Mile High Flood District, please contact:

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Disclaimer

This analysis in this How-To Guide was prepared using ESRI ArcGIS version 10.2.2 with the 3D Analyst and Spatial Analyst extensions. Using newer or older versions or different GIS software, such as QGIS, could require use of different tools. Additionally, this Guide assumes the user has a basic knowledge of ArcGIS and the use of the ArcToolbox to conduct spatial analyses. No warranties are made regarding the likelihood that a LOMA submitted based on data processed using this method will result in an approved LOMA. Eligibility for a LOMA does not preclude a property from being at risk of flooding. It is highly recommended that property owners maintain flood insurance even if a LOMA is granted.

Added Benefits of this Analysis, even if a LOMA cannot be submitted.

Even if a structure does not qualify for a LiDAR LOMA, there are other useful benefits to this process. The structure could have the first floor elevated higher than the ground potentially making it suitable for a traditional LOMA. The information gathered at a larger scale could also help identify potential areas of mitigation interest. For instance, if a new bridge or larger culvert could be constructed that reduced flooding enough to remove numerous structures, this data could help demonstrate the benefit of completing the project. If a community participates in the Community Rating System, doing this exercise could allow for credit through Activity 322d, Maintaining Flood Depth Data.