Coordinate Systems

Trouble-shooting and exploration

Written by Barbara M. Parmenter. Revised for 10.8.1 (remote) on 2/15/21. Revise and last updated 9/10/2021

Contents

Introduction and Objectives

In is an exercise you will familiarize with coordinate system concepts using ArcGIS Pro. A solid understanding of coordinate systems is critical for GIS users. Selecting an appropriate coordinate system is necessary for good visualization and analysis. The accuracy of spatial queries, overlays, and calculations (e.g., area and perimeter) rely on accurate coordinate system and projection choices. The issues may manifest themselves as errors that preclude completion of a certain query or calculation, or errors in the results of a query. For example, you should not calculate the area of polygons for a data set that is in a Geographic Coordinate System (GCS), and not projected. In addition, spatial queries in a GCS coordinate system may not perform properly. If you are using an inappropriate Projected Coordinate System (PCS), your selections based on spatial relationships ("show me all the buildings within 2 miles of a geologic fault line") and your area/perimeter/length calculations can be completed, but they may have significant errors.

The learning objectives for this exercise are:

- Explore ArcGIS Pro to get information about a data set's coordinate system
- Change the coordinate system of a Map in ArcGIS Pro
- Describe the steps on how to select an appropriate coordinate system for a given area
- List some of the the problems that might occur in GIS due to map projection and coordinate system issues

In a nutshell:

- It is crucial to be aware of the coordinate system for your Map and for each one of your data sets (layers).
- It is important to work within an appropriate projected coordinate system for your area of interest. In order to accomplish this, you need to know your goal.
- When performing spatial analysis (where spatial relationships matter – e.g., spatial overlays, proximity functions, and area/length/perimeter calculations), all the data sets involved need to be in the SAME projected coordinate system.
- It is recommended to make sure your Map and layers are in the same projection.
- Many of the most common problems encountered by GIS users turn out to be related to coordinate system issues. This tip sheet takes you through several common issues you'll encounter in GIS that have to do with coordinate systems.

For more information, please check the following guides:

- Coordinate systems, projections and transformations (also: https://pro.arcgis.com/en/pro-app/latest/help/mapping/properties/coordinate-systems-and-projections.htm).
- What are map projections? (also: https://desktop.arcgis.com/en/arcmap/latest/map/projections/what-are-map-projections.htm).

Copying the Map Projection Exercise Folder

- Download the *CoordinateSystems_Data_Project.zip* file from Canvas and save it in your Box folder account or Downloads (whatever the case is).
- Once you have it in your Box folder or Downloads folder, right-click and Extract All.
- On your folder, look for the project package *Projection_ArcGISPro_Package.ppkx*
- Double click on it to open it.

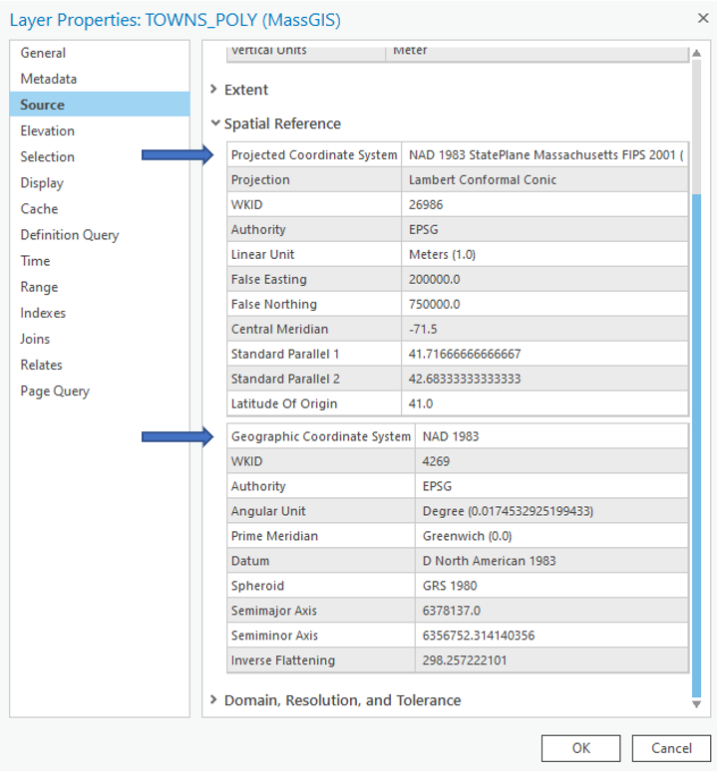
Coordinate System and Projection of a Data Set

It's critical that you know the Geographic Coordinate System of each of the data sets you are using.

Each data set (or layer) is in a specific coordinate system. But what is a coordinate system? A coordinate system is the most general term for a system that includes coordinates. Coordinate systems are required information needed to create the dataset – without this information, the software wouldn't know where to "place" your data in the world. Nowadays, most GIS data sets will have a defined geographic coordinate system, but may not have a defined projection. You can find out what a data set's coordinate system and that's what we will do in this exercise.

Follow these steps to find out what Geographic Coordinate System and Projection a dataset or layer is using:

1. Right-click on the *Towns_Poly* layer in the Contents Pane and choose Properties, then click the Source tab. The Source Tab contains lots of important information about the Data Source, Extent, Spatial Reference, and Domaine, Resolution, and Tolerance.
2. Click on Data Source. Review all information.
3. Click on Spatial Reference and expand. Check that there's information in both "Projected Coordinate System" and "Geographic Coordinate Systems". Check on the units and respond:



Questions

1. Is this layer projected?
2. If so, what is the projection name, projection type, and what is the geographic coordinate system?
3. What are the units displayed under the Projected Coordinate System?
4. What are the units displayed under the Geographic Coordinate Systems?

Note: All Projected data has a Geographic Coordinate System, but data that is just in a Geographic Coordinate System does NOT necessarily have a projection.

Coordinate System of the Map

It's critical to know the coordinate system of the Map you are working with. The Map ALWAYS takes on the coordinate system information (projection or not) of the Base Map (usually WGS 1984 Web Mercator, auxiliary sphere) when you start a new project in ArcGIS Pro. However, you can always change it.

Any layers you add might include a projection that you can use to "project on the fly" your map. This means if you pull in a dataset that has different coordinate information than the Map, the data will act as if it's in whatever coordinate system your Map is set to.

If you know you have data in a projection you want to use, you should pull this layer into your ArcGIS Pro session and use it to define the Map's projection. Again, you can always change the Map's or layer's coordinate system if you need to.

In order to view the coordinate system of your Map in one of two ways in ArcMap:

1. Simply double click on top the Map "*World Data*" (Properties will appear)
2. Right-click on "*World Data*" Map and go to Properties

Question

5. What is the coordinate system information of the World Data Map? Is it projected?

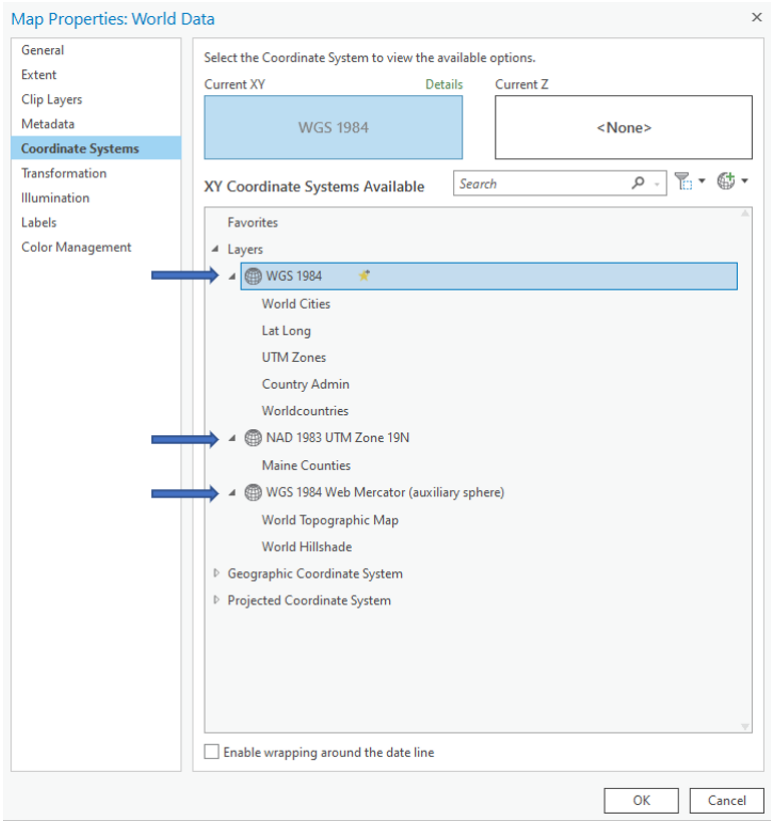
Note: don't close the properties quite yet…

Finding the coordinate systems of all layers in a Map

It is easy to find all layers' coordinate system. Go to Coordinate Systems within the Map Properties > under XY Coordinate Systems Available expand Layers.

Question

6. Out of the list, which datasets are projected and which are not?
7. Are all the projected data layers in the same projection?
8. Are the World Countries data sets projected?
9. Why do you think the Maine Counties data set isn't using a State Plane coordinate system? (Hint: in ArcGIS Pro, turn on the State Plane Zones NAD83 layer and zoom in to Maine - and remember that State Plane zones are for local mapping.)



Setting a Coordinate System for Mapping

We've discussed in class the different types of coordinate systems and projections, and when one is more

appropriate than another. You can also review the ArcGIS Pro web help section for Supported Map Projections for advice.

In this ArcMap session, we have three coordinate system grids pulled in to help us visualize the difference:

- State Plane Zones NAD 83 of the US (zone names will appear if you zoom in below 1:20,000,000 scale).
- A 10 x 10 Degree Graticule which shows latitude and longitude (in 10-degree blocks and decimal degrees units).
- UTM Zones of the world (zone labels are at the top)

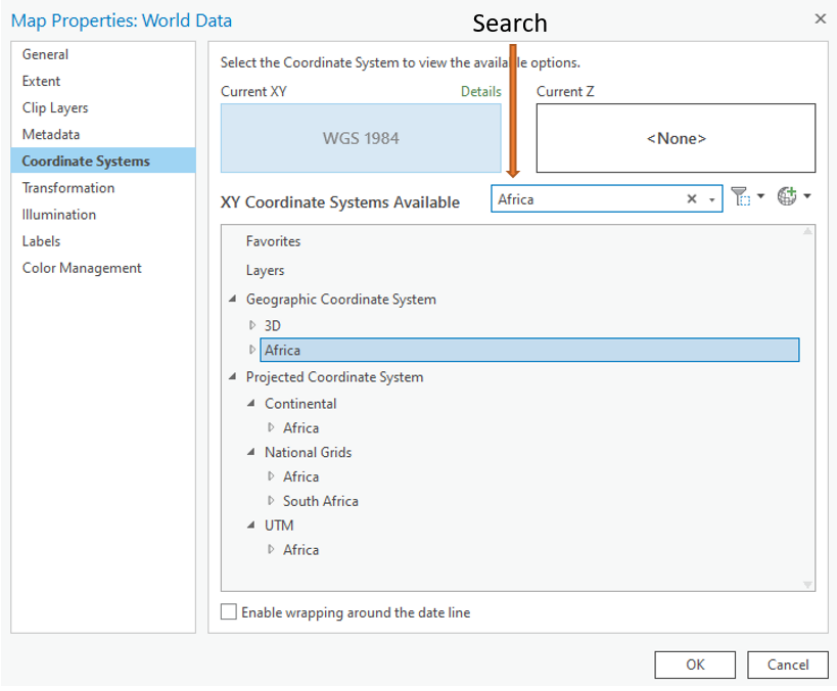
Take a look at the UTM and *State Plane Zones (NAD83)* - zoom in to a state or group of states to see the State Plane zones more clearly.

- The UTM Zones Coordinate System (i.e., *State Plane Zones (NAD83)*) was developed to facilitate accurate mapping for both local and regional mapping. They are especially useful for regions that extend north/south.
- The various State Plane Coordinate Systems were developed primarily to facilitate local mapping (at the city or metropolitan scale).
- The *Lat Long (10 x 10 Degree)* Graticule Geographic Coordinate System is not a projected coordinate system – it is a useful way to distribute data for large areas (e.g., the US or the World,) but you should always choose a projected coordinate system when using this data in a map or for spatial analysis.

To create a good map with an appropriate projection, you can change the Map's coordinate system by going to the Map's Properties Coordinate System tab and define a new Coordinate System. This will be determined by the "place" you will be focusing on.

We have talked about the several coordinate systems in class. Note there are many coordinate systems and map projections that ArcGIS makes available. For example, to make a map of the continent of Africa, you might want to choose a map projection specifically designed for that – recall that Conformal means the map projection retains angular relationships and the accurate shapes of features as much as possible, and that Equal Area means that the projection retains accurate area and relative sizes and of features as much as possible.

In ArcGIS Pro, you can type in keywords to find an appropriate coordinate system. For example, let's continue with the example of Africa. Under the **Map Properties:** *World Data*, type under the Search space, "Africa". The results returned will be several (see figure below).



Set an appropriate coordinate system to your map

Based on what you have learned in class, and using the UTM Zones and State Plane Zones grids to guide you

where appropriate, choose four of the following areas and set an appropriate coordinate system for the data frame for each in turn.

1. To do so, click on the **Map Properties > Coordinate System** tab.

2. Choose either from the Projected Coordinate Systems area or if one of the layers on the map has what you want, you can choose from the Layers section. When you see choices, look for **NAD 1983** and **WGS 1984** as the best options North American locations (NAD 1983) or the rest of the world (WGS 1984) respectively.

Task

10. Pick four locations from the following list and set the correction projection through the Data Frame properties for each. For each location you choose, take a screen shot of the ArcGIS Pro with the projection set (and zoomed into the area of interest) and write down the projection information (projected coordinate system name, Projection type, the Linear Unit.

- The Florida Panhandle
- Washington, DC
- Nantucket
- Chicago
- San Francisco metropolitan region
- All of California
- Port au Prince, Haiti
- Maine
- Honduras
- South Korea
- Montana
- Canada
- Europe
- New Delhi, India
- Somerville, Massachusetts
- All of Brazil
- A continent of your choice, for purposes of showing the most accurate shape of features
- A continent of your choice, for purposes of showing the most accurate area of feature

Troubleshooting missing/incorrect spatial references

In this section you will learn how to handle data sets that are missing a spatial reference or that have the wrong spatial reference.

1. In your project, click on the Map *Boston*

We are zoomed into Boston, with the MassGIS Towns poly layer and the Boston Redevelopment Authority's Planning District layer (*Boston Neighborhoods90*).

Questions

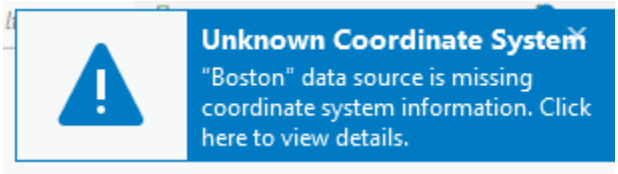
11. What are the coordinate system and linear units of each of these layers? Write them down.
12. What is the coordinate system and linear units of the *Boston* Map? Write it down.

It's fairly common that city planning departments use the "feet" version of their area's State Plane coordinate system, while MassGIS uses the "meter" version. The point is that both data sets appear together in the correct

location even though they are in different coordinate systems (one based on feet and the other on meters). This works because ArcGIS Pro knows what those coordinate systems are, making them both appear to be in the data frame's State Plane meter projection!

Occasionally, a dataset's coordinate system has NOT been defined explicitly by its creator. Every GIS data set is in some coordinate system, and the ArcGIS software sees these coordinates. But unless the data creator has explicitly recorded the coordinate system of the data, the ArcGIS Pro has no way of knowing what system these coordinates represent, so no way of knowing where in the world they may be.

When you try to add a data layer that has no defined coordinate system to your ArcMap session, you'll get an error message like this:



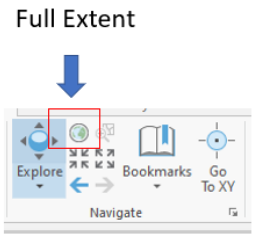
The data layer might draw, but it may or may not draw in the right place! And when using data that has a missing spatial reference, problems will be present.

Adding data from the City of Newton

1. Connect the folder *Newton_Data*, under the *CoordinateSystems_Exercise*

> Question
>
> 13. What happened when you added the buildings layer? Where has the data been placed? What else is at this location?

2. Right-click on building footprints *bldgfoot* and choose Zoom to Layer. Do you have any idea where this data is located?
3. Click on the full extent button. Can you see where the Newton data layers were placed? This is nowhere near the City of Newton.



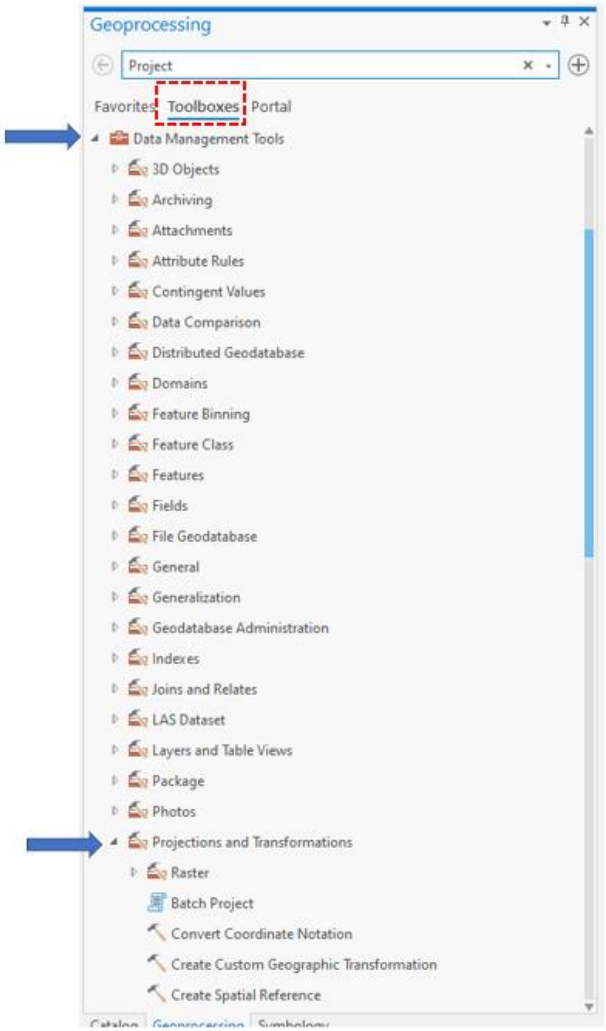
Assigning a Projection

We asked the City of Newton what coordinate system they use when they make their data; the information received was: Massachusetts State Plane Mainland, NAD 83, with linear units of FEET.

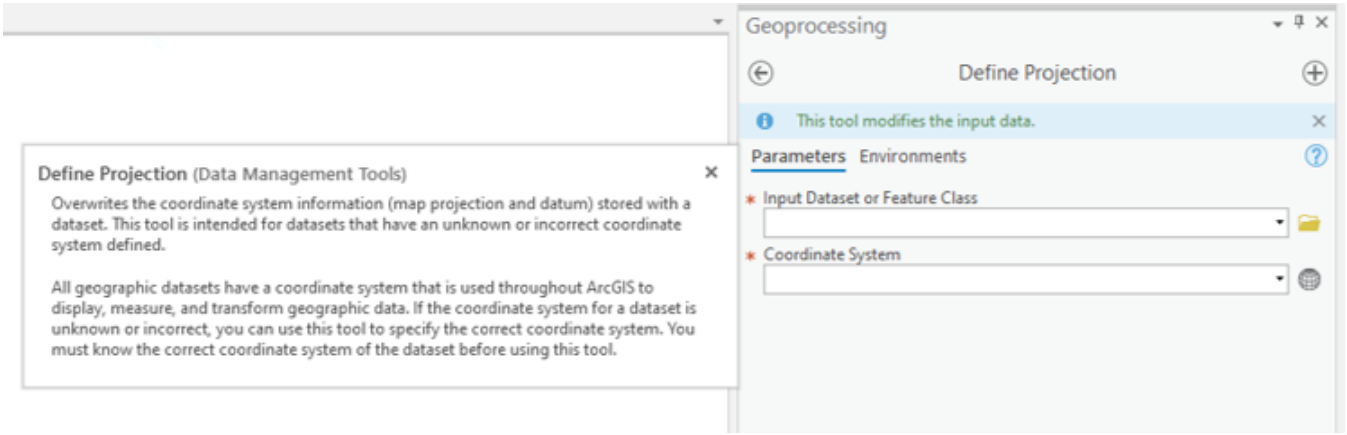
The building footprint data set's coordinate system is missing a spatial reference and needs to be defined. Once the information is acquired, the process of defining the projection for the data set is possible. This process will create a small projection file (**.prj*) that will then reside with the data set (in this case, the *shapefile*).

We will use the geoproecessing tools. The easiest way to find a tool is by doing a quick search.

1. Click on the menu Analysis → **Tools** icon. The Geoprocessing window will appear.
2. Under the ***Find Tools*** area type "Define Projection" followed by enter key
3. The first option will be Project (Data Management Tools). That means that you can look by navigating tools, find the tool Project under that group of tools (see image below).



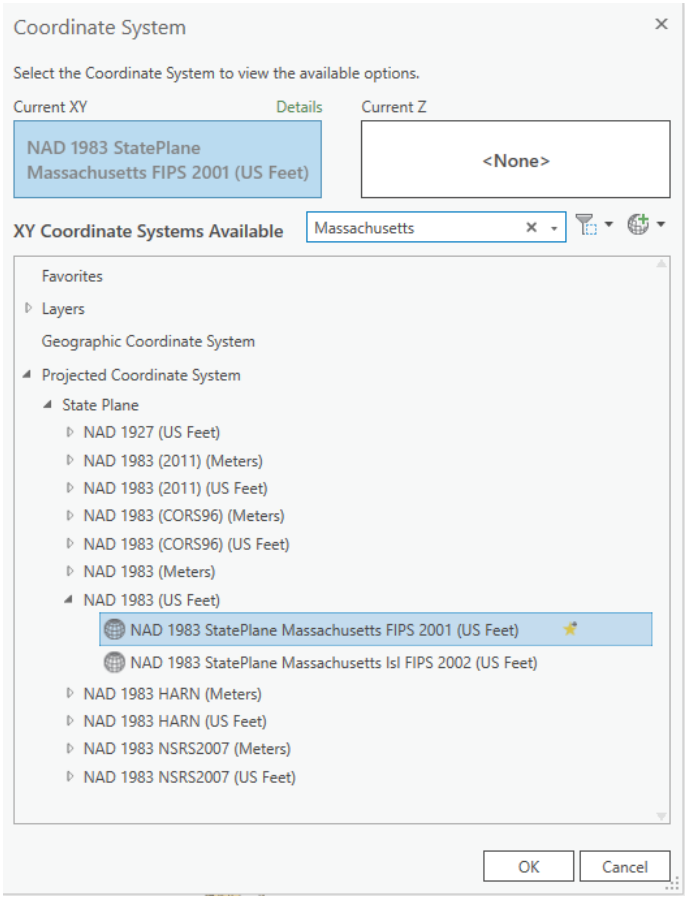
Click on Show Help at the bottom of the tool. This tool assigns a projection to a dataset with MISSING spatial information. It SHOULD NOT BE used to change a projection of an already projected layer.

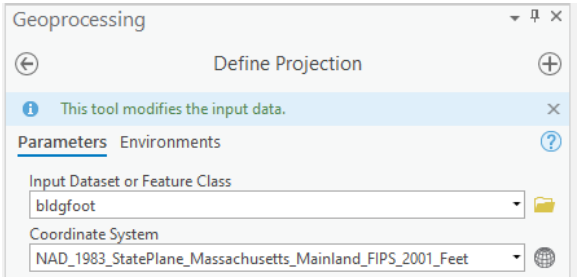


4. For the Input Dataset click on the black arrow to select *bldgfoot* (you can either drag the layer or select it from the drop-down arrow).
5. Click on the icon for Select Coordinate System 
6. Type in the *Search* box, "***Massachusetts***". You will notice that only the *Projected Coordinate Systems* will

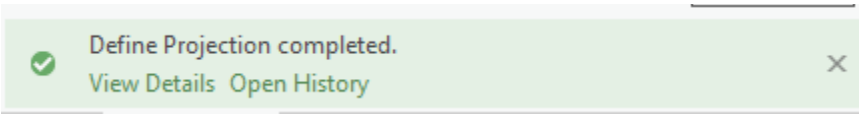
be available.

7. Expand the *State Plane* option > **NAD 1983 (US Feet)**
8. You will find two options. Select **NAD 1983 StatePlane Massachusetts FIPS 2001 (US Feet)**.
9. Click **OK**. You will see now the coordinate system selected.
10. Click **Run**.





Once the tool finishes the process, you will see a message Define Projection Completed.



11. Now, right click on the *bldgfoot* layer and press zoom to layer. Do the Newton building footprints show up in the right place?

We have now assigned the layer (which was missing ANY spatial information) the correct State Plane coordinate system information.

Are building footprints now in the correct location?

You have now learned to define coordinate systems. The most important points here are:

- You should never work with data sets that are missing a spatial reference
- You need to know what the spatial reference is for the data set before you can use the DEFINE PROJECTION tool

- You need to investigate the accompanying documentation or make phone calls to find out what the data set's coordinate system really is – it has one, you just don't know what it is.
- Never, ever, ever, ever, ever use the DEFINE PROJECTION tool to define the coordinate system you would like the data set to be in if you DO NOT KNOW what it really is! What you want does not matter! You need to know what coordinate system the data set IS in. If you start guessing you can make matters much, much worse!

Setting up for Spatial Analysis

Projecting your Data

The last important thing you need to know is that for performing spatial analysis, it is good practice to put your data frame and all the data sets that are part of the analysis into the SAME projected coordinate system. By spatial analysis, we mean doing queries and analysis that involve spatial relationships, like **calculating area, creating buffers, select by location, and various overlay tools**. If you are only mapping things, then the data sets can remain in their own coordinate systems, as long as these are all defined and the Data Frame is in the correct projection! But if you start doing spatial analysis, then it is best to make copies of these data sets that are in a shared projected coordinate system.

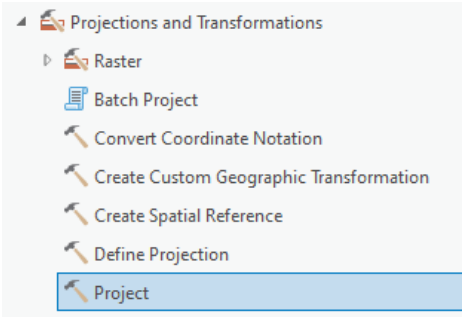
Let's say that we want the Newton building footprints data layer to be part of a spatial analysis involving 3 data sets from MassGIS. The Newton building footprints layer is in the **Mass State Plane Mainland NAD 83 (feet)** coordinate system, and the MassGIS data is all in **Mass State Plane Mainland NAD 83 (meters)**.

Let's also assume we have decided that the **Mass State Plane Mainland NAD 83 (meters)** coordinate system is the one we will use for our project (our project is all in Massachusetts and most of our data layers come from MassGIS, so using the Mass State Plane Mainland NAD 83 (meters) is a good choice.

1. First, check your Map's properties to ensure that it is in your target coordinate system - **Mass State Plane Mainland NAD 83 (meters)**.

We are going to make a new dataset of the Newton building footprints which will be in the same coordinate system and linear units as the MassGIS data sets, by using the **Project** tool (see the following link to get more information about this tool: https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/project.htm). The Project tool does not assign a projected or geographic coordinate system as the **DEFINE PROJECTION** tool does – rather it makes a **COPY** of the original data and set in a NEW projection.

2. Click on the menu **Analysis → Tools** and use the search window to look for **Project** (simply type the word project). Otherwise, you can also find it under **Analysis → Tools → Data Management Tools → Projections and Transformations → Project.**

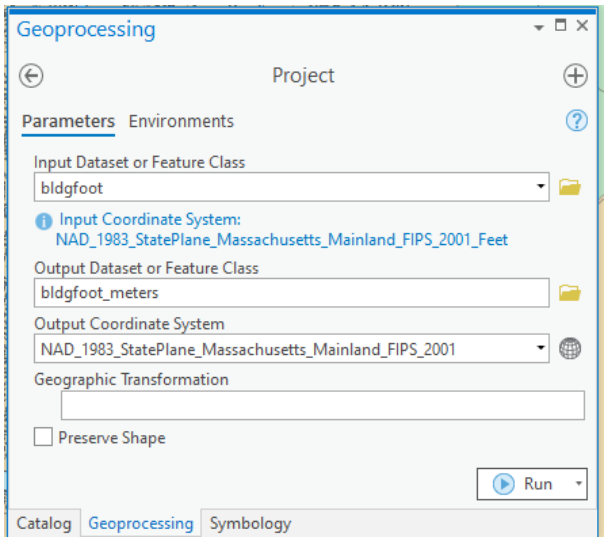


3. Once you have Project in your Geoprocessing window, start by filling out the dialog box with the layer of interest *bldgfoot*
4. Note the tool will create a new output data set that is a copy of the Building Footprints (*bldgfoot)*, but in the new coordinate system you will define.

Notice how the Output Dataset or Feature Class assigns the same name of your file with the additional underscore and project; change it to *bldgfoot_meters*. You can leave it like that for now.

5. On the Output Coordinate System, click on Select Coordinate System, and on the search window, type again **Massachusetts** and click enter.
6. Select **NAD 1983 (Meters)**; expand. Next, select **NAD 1983 StatePlane Massachusetts FIPS 2001 (Meters)**

7. Leave **Geographic Transformation (optional)** empty.
8. Click Run.



The dataset will be added automatically to your Map.

9. Click Run.
10. Remove the older building footprint data set so you don't get confused on which one to use in your analysis.

You can do this with other data layers as well, as long as they have a correctly defined coordinate system.

READ THE FOLLOWING

Warning: If you incorrectly define a data layer's coordinate system using the **DEFINE PROJECTION** tool, and then convert it into a different coordinate system using **PROJECT**, you are going to be confused and frustrated. Hence, as soon as you detect it, you know you did something wrong. There are different ways to correct the error.

DEFINE PROJECTION is for defining the coordinate system of an existing data set when that data set's coordinate system is missing. Only use this is you get a warning that a data set is **UNKNOWN COORDINATE SYSTEM**. The DEFINE PROJECTION tool does NOT make a copy of the data set – it changes the original data set!

PROJECT creates a new copy of the data set in the desired projection. Use this to prepare data sets for spatial analysis after you have decided on what your map projection will be for your analysis.

So be careful and always…

Practice safe mapping – define your projection!