Proximity Exercise: A Risk Assessment for Nuclear Power Plants in Southern New England

Written by Barbara Parmenter. Revised 4/4/2017

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Introduction

In this exercise, we'll be doing a simple analysis of the population at risk around New England's four nuclear power plants and exploring potential evacuation centers and routes. You'll practice using the following tools:

- Select by location
- Statistics
- Spatial Join
- Buffer and multi-ring buffer
- Near tool
- Point distance tool
- Network analysis – service area

Data Sets and Sources

The data sets have been acquired and pre-processed as described below. New England states refer to Connecticut, Rhode Island, Massachusetts, Vermont, and New Hampshire.

Directions on how to access the data are in the next section. You do NOT need to download all this data!

Northeast_states_UTM19N

Data Source: Mapcruzin.com (http://www.mapcruzin.com/nuclear-power-plant-earthquake-shapefiles/), US basemap.zip, downloaded 3/30/2011.
Processing: The five New England states plus New York were selected out and exported to the UTM WGS 1984 Zone 19N coordinate system

Nuclear_Power_Plants_UTM19N

Data Source: Mapcruzin.com (http://www.mapcruzin.com/nuclear-power-plant-earthquake-shapefiles/), downloaded 3/30/2011.
Processing: The four New England power plants were selected out and exported to the UTM WGS 1984 Zone 19N coordinate system

Airports_UTM19N

Data source: Bureau of Transportation Statistics, National Transportation Atlas Database, 2010 (http://www.bts.gov/publications/national_transportation_atlas_database/2010/), downloaded 3/30/2011
Processing: Airports in the 5 New England states were selected and exported to the UTM WGS 1984 Zone 19N coordinate system

National_Highway_Planning_Network_UTM19N

Data source: Bureau of Transportation Statistics, National Transportation Atlas Database, 2010 , NHPN, Region 1 (http://www.bts.gov/publications/national_transportation_atlas_database/2010/), downloaded 3/30/2011
Processing: The roads and highways were exported to the UTM WGS 1984 Zone 19N coordinate system

EPA_region1_schools_UTM19N

Data source: EPA Region 1 public schools, accessed via Geodata.gov (http://gos2.geodata.gov/wps/portal/gos), published 2008, downloaded 3/30/2011
Processing: Schools were exported to the UTM WGS 1984 Zone 19N coordinate system

2000_blockpop_centroids_UTM19N

Data source: ESRI, Census 2000, M:\\ESRIDataMaps93\Census\Blockpop.shp
Processing: Census block points within southern New England, eastern New York and Long Island were selected graphically and exported to the UTM WGS 1984 Zone 19N coordinate system

Important attribute column names note:
Pop2000 – 2000 Census population count
HSE_Units – 2000 Census housing unit count
Household – 2000 Census household count (a household = people sharing one housing unit)

Hospitals_UTM19N

Data Source: US Department of Health and Human Services, HRSA Geospatial Data Clearinghouse – ArcIMS Server: datawarehouse.hrsa.gov, Service Name: HGDW_Mapping (ArcGIS directions can be found here: http://datawarehouse.hrsa.gov/HGDWFeatureService.aspx)
Processing: All US Hospitals were exported out of the ArcIMS server, then the hospitals in the 5 New England states were selected and exported to the UTM WGS 1984 Zone 19N coordinate system.

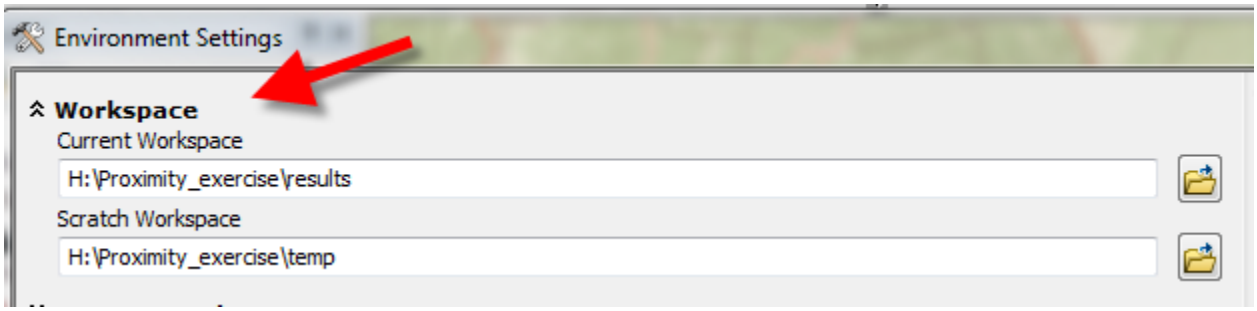
Important attribute table column names note:
HRSAgeo_5 = provider category code
HRSAgeo_6 = provider category description
HRSAgeo_7 = category sub-type code
HRSAgeo_8 = provider category sub-type description
HRSAgeo9 = Facility Name
HRSAgeo10 = Total Bed Count
HRSAgeo_11 = certified bed count

Accessing and Preparing for the Tutorial

1. From *S:\Classes\DHP_P207* copy the **Proximity_Exercise** folder to your H: drive.

a. You can also download the data from the link on the Tufts' GIS website (here).

2. Open the **Proximity_Exercise** folder in your H drive and double-click on **Start_map.mxd** – this will start ArcMap.
3. In ArcMap, go to **Customize → Extensions** – and checkmark *Spatial Analyst* and *Network Analyst.*
4. Take a couple minutes to explore the different data layers – look at their attribute tables especially.
5. Click on **Geoprocessing – Environments…**
6. In the Environment Settings box, click on Workspace.
7. Set the **Current Workspace** to be your *Proximity_Exercise\Results folder* and your **Scratch Workspace** to *Proximity_exercise\Temp folder* (read about the difference by clicking on "Show help" at the bottom right for both the "Scratch Workspace" and "Current Workspace"):



Select by Location - population estimations in 12 and 50 mile zones around the four nuclear plants

Using the tools you already know, how would you estimate the population within a 12 mile (20km) zone of Southern New England's four nuclear power plants? (Hint: Select by location, statistics)

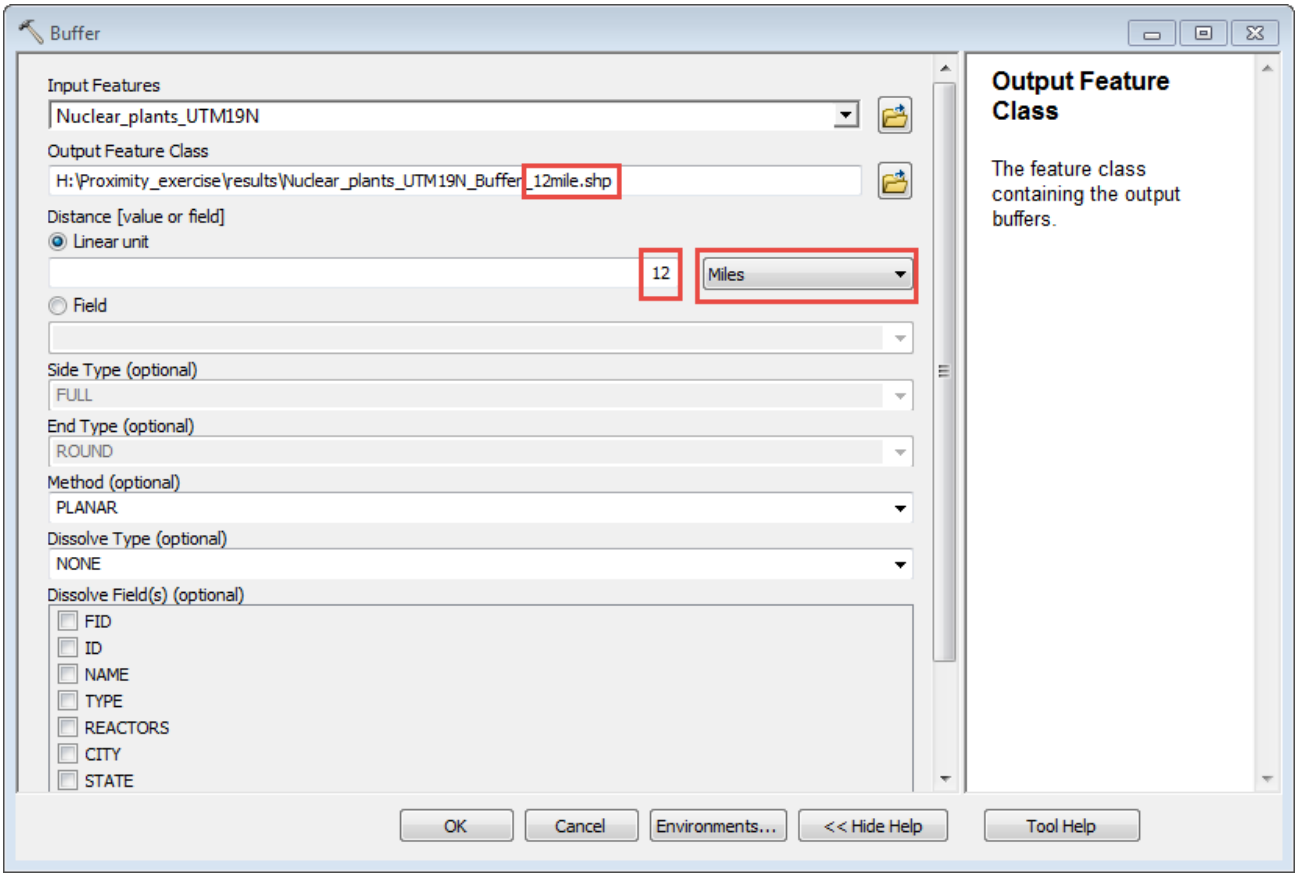
How many households are there? How many housing units? Why might we want to know population, households, and housing units, rather than just one of these numbers?

Estimate the population within a 50 mile zone.

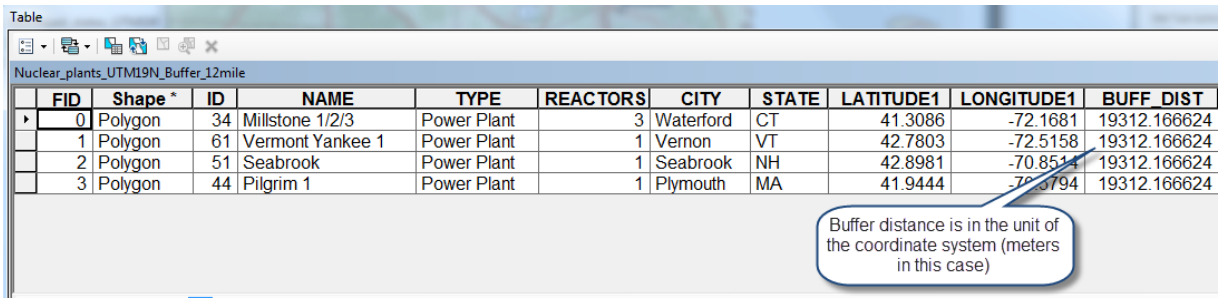
Buffer Tools - Visualizing a 12 mile and 50 mile evacuation zone

While select by Location is useful, **Buffers** can help us visualize zones and perform further analysis. We are going to create **Buffers** 12 miles and 50 miles around these Nuclear Plants.

1. Click on the **ArcToolbox** icon to open it.
2. Click on **Analysis Tools → Proximity** – you'll see **Buffer** and **Multiple Ring Buffer.**
3. Double-click on **Buffer.**
4. Click **Show Help –** as you saw above, the Help is context sensitive, so when you click on a box, it will tell you what to do.
5. Fill out the dialog box as you see below (using your personal folder path), making sure to include "12mile" in the new file name:



6. Press OK.
7. When the processing is complete, click Close and if prompted, view the results on your map. The buffer layer you just created will appear automatically in your table of contents.
8. Click on **File→ Save As** and save your mapfile as *Proximity1.mxd*
9. You can set the 12-milebuffer zones to be semi-transparent by right-clicking on the buffer data layer and going to *Properties →Display*. Seet the Transparent: field to 50%.
10. Open the attribute table of the new buffer data layer. What do you see?



The difference between a dissolved buffer and a non-dissolved buffer

When you created that buffer, you chose **NONE** for the *Dissolve Type.* This creates a **separate** buffer around each plant (point). If you choose **DISSOLVE**, all your buffers would be one feature, shown in one row, and the attribute information of the nuclear power plants would be lost. By keeping the Dissolve Type option set to none, you have the four separate buffer features, with the associated nuclear power plant information.

If you wanted to create a 50 mile zone around each plant, you could repeat the buffer process and specify 50 miles.

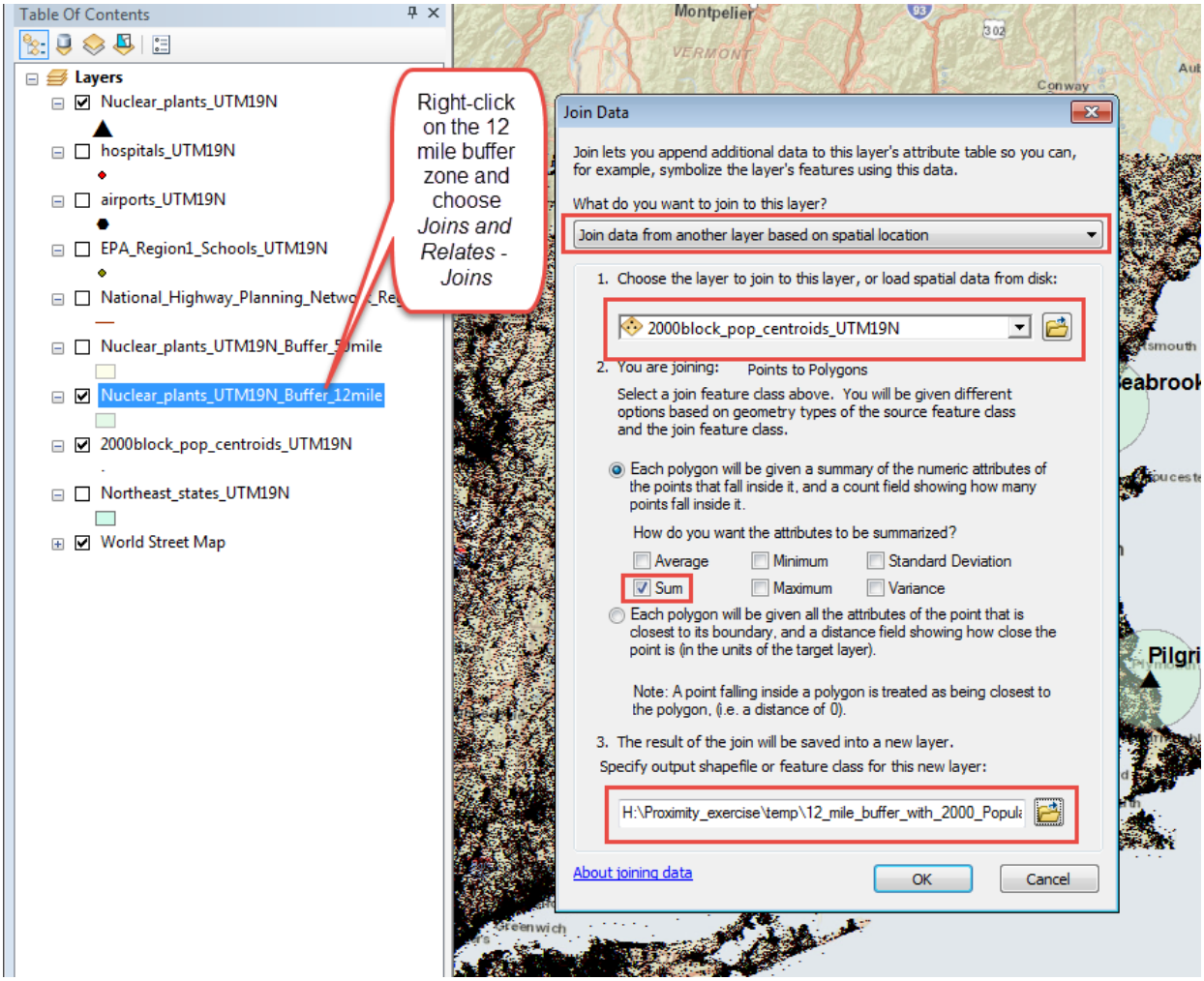
We will base the rest of our analysis on the 12 mile zones, so make sure your 12 mile buffer is turned on.

Performing a spatial join to estimate the population with 12 miles of each nuclear power plant

If we want to know the population within 12 miles of each nuclear power plant, we could select each plant one at a time, and then select all the 2000 blockpop centroids within 12 miles of the selected plant, then look at the attribute table. And do this individually for each plant.

Or we can use a function called a ***Spatial Join***, which makes it much easier and joins the population data INTO each of the buffers.

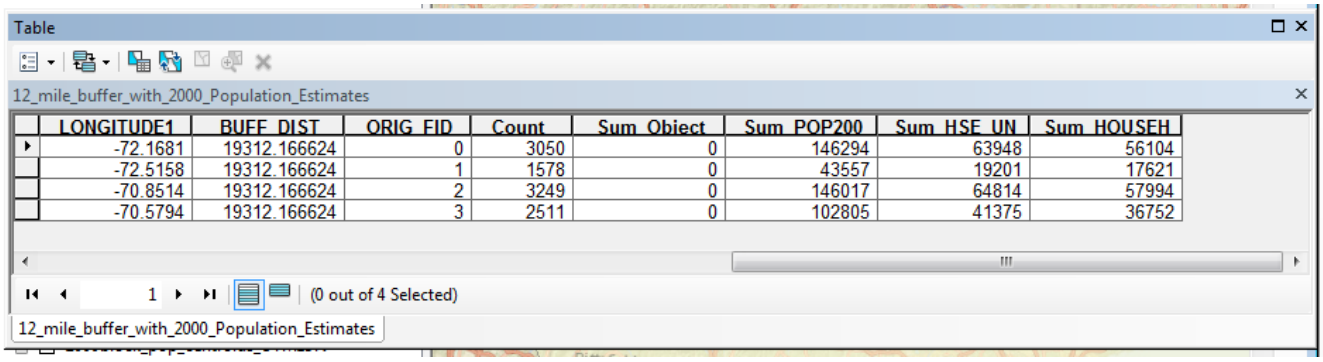
1. Follow the graphic and name the output file **12_mile_buffer_with_2000_Population_Estimates.shp**.



This may take a few minutes. A new layer is created, which *looks* the same as the buffers but when you explore the attribute table, you see that the population data from the underlying blocks are summed for each 12 mile buffer zone!

Why did we select sum instead of average in the spatial join? We did this because we wanted the sum of all the block groups within a buffer so we could know the **total** population, rather than the average for just 1 block group in the zone.

Explore the resulting attribute table of the **12_mile_buffer_with_2000_Population_Estimates.shp .** The **sum** of population and households is at the far left of the table. The count field is the number of blocks within each buffer.

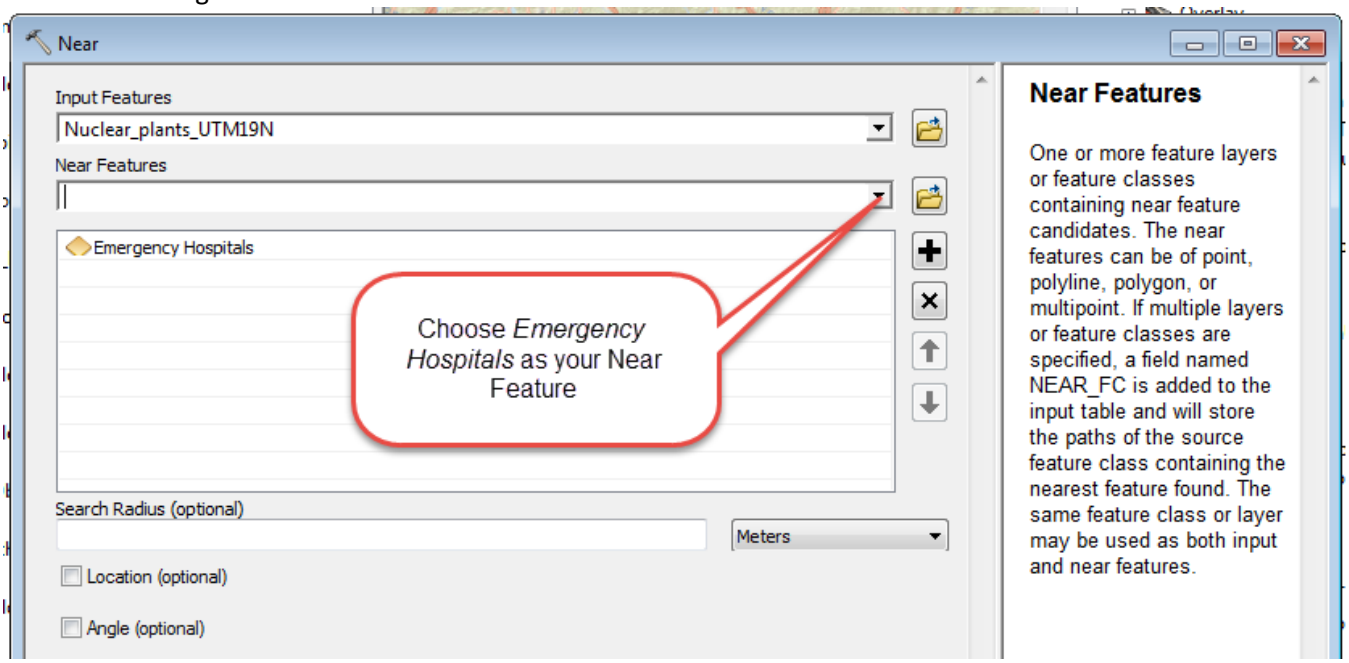


LONGITUDE1	BUFF_DIST	ORIG_FID	Count	Sum_Object	Sum_POP200	Sum_HSE_UN	Sum_HOUSEH
-72.1681	19312.166624	0	3050	0	146294	63948	56104
-72.5158	19312.166624	1	1578	0	43557	19201	17621
-70.8514	19312.166624	2	3249	0	146017	64814	57994
-70.5794	19312.166624	3	2511	0	102805	41375	36752

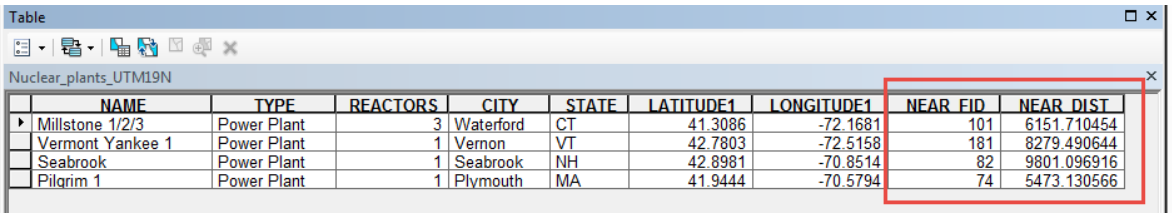
NEAR Tool – what is the nearest hospital to each nuclear plant and how many beds does it have?

For better emergency planning, we now want to know the nearest hospital to each nuclear plant and how many beds it has for emergency training and planning purposes. The near tool examines the closest feature in another field to each point in the original field. However, rather than following a road network, it measures distance "as the crow flies" – aka a straight line from point to point, not taking into account roads.

1. Turn on Hospitals and look at its attribute table. Which type of hospital would be good to serve as a medical provider in the event of an emergency at a nuclear plant? (*HRSAgeo_8* has the hospital sub-type description)
2. Use **Select by Attribute** to select the *short term hospitals.*
3. Create a **new layer selection** from the selected hospitals and call it *Emergency Hospitals.*
4. Go to **ArcToolbox → Analysis Tools → Proximity** and double-click on **NEAR** – make sure to *Show Help* and read about what the tool does.
5. Fill out the dialog box as follows:



6. Click OK
7. This tool adds two new fields to your ***Nuclear_plants_UTM19N*** **attribute table** – open the attribute table to see.
8. Scroll to the end of the table. You see NEAR_FID and a NEAR_DIST. The NEAR_FID is the Feature ID (FID) of the nearest hospital. The NEAR_DIST is the distance (straight line) to the nearest hospital. Note the NEAR_DIST is measured in the same units used by the coordinate system, so in this case they are in meters.

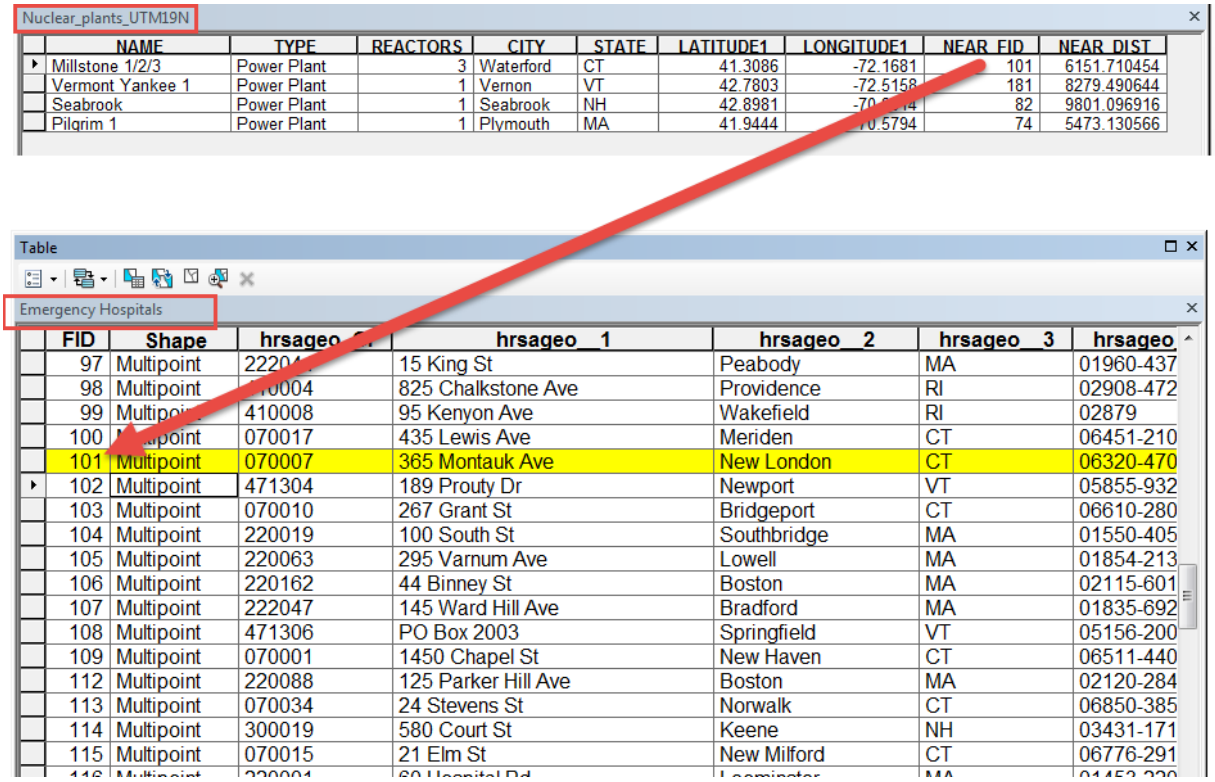


Table

Nuclear_plants_UTM19N

NAME	TYPE	REACTORS	CITY	STATE	LATITUDE1	LONGITUDE1	NEAR_FID	NEAR_DIST
Millstone 1/2/3	Power Plant	3	Waterford	CT	41.3086	-72.1681	101	6151.710454
Vermont Yankee 1	Power Plant	1	Vernon	VT	42.7803	-72.5158	181	8279.490644
Seabrook	Power Plant	1	Seabrook	NH	42.8981	-70.8514	82	9801.096916
Pilgrim 1	Power Plant	1	Plymouth	MA	41.9444	-70.5794	74	5473.130566

9. If we open up the **Emergency Hospitals** table, you'll see the FID at the very beginning of the table. If you look at the Nuclear Plant attribute table, we find the nearest hospital to the Millstone Power Plant in Waterford, CT, is the Lawrence and Memorial Hospital located approximately 6151 meters away. See the next page for a graphic of this:


Nuclear_plants_UTM19N

NAME	TYPE	REACTORS	CITY	STATE	LATITUDE1	LONGITUDE1	NEAR_FID	NEAR_DIST
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Pilgrim 1	Power Plant	1	Plymouth	MA	41.9444	-70.5794	74	5473.130566

Table

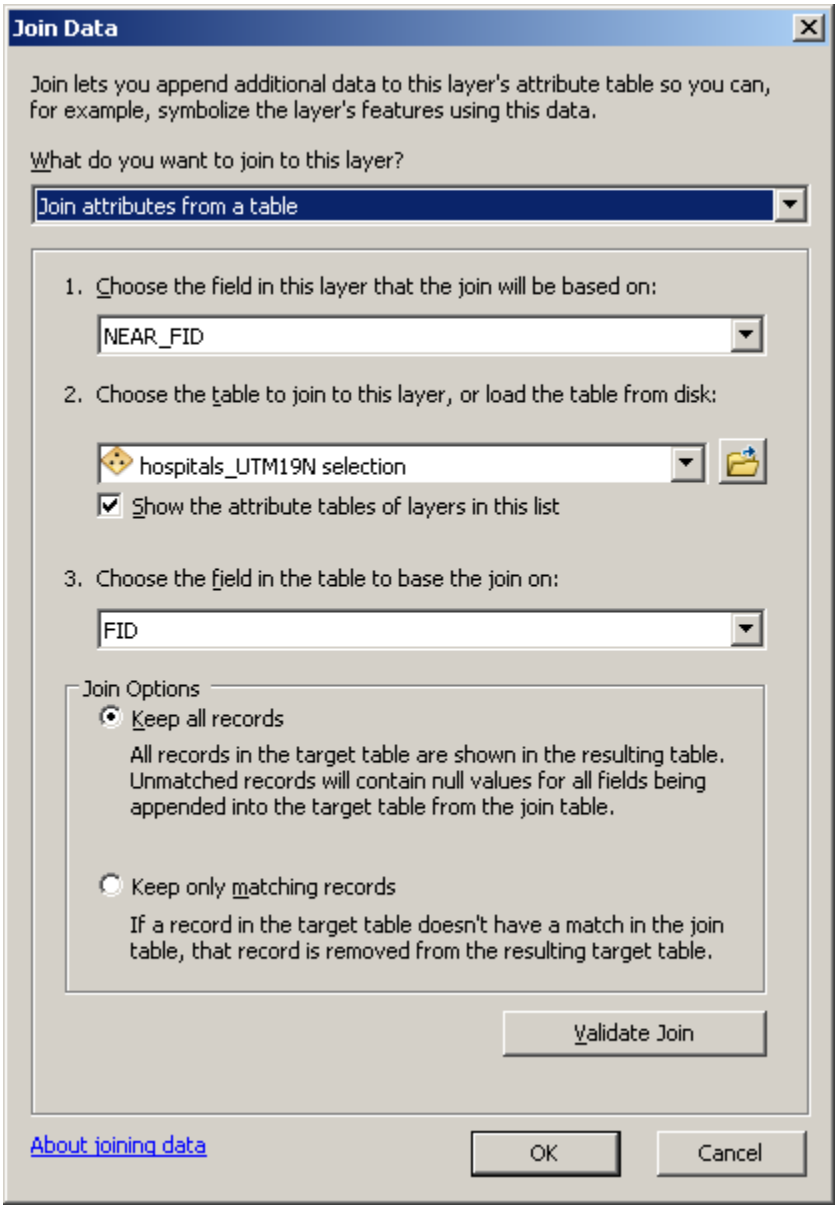
Emergency Hospitals

FID	Shape	hrsageo_	hrsageo__1	hrsageo__2	hrsageo__3	hrsageo
97	Multipoint	2220	15 King St	Peabody	MA	01960-437
98	Multipoint	410004	825 Chalkstone Ave	Providence	RI	02908-472
99	Multipoint	410008	95 Kenyon Ave	Wakefield	RI	02879
100	Multipoint	070017	435 Lewis Ave	Meriden	CT	06451-210
101	Multipoint	070007	365 Montauk Ave	New London	CT	06320-470
102	Multipoint	471304	189 Prouty Dr	Newport	VT	05855-932
103	Multipoint	070010	267 Grant St	Bridgeport	CT	06610-280
104	Multipoint	220019	100 South St	Southbridge	MA	01550-405
105	Multipoint	220063	295 Varnum Ave	Lowell	MA	01854-213
106	Multipoint	220162	44 Binney St	Boston	MA	02115-601
107	Multipoint	222047	145 Ward Hill Ave	Bradford	MA	01835-692
108	Multipoint	471306	PO Box 2003	Springfield	VT	05156-200
109	Multipoint	070001	1450 Chapel St	New Haven	CT	06511-440
112	Multipoint	220088	125 Parker Hill Ave	Boston	MA	02120-284
113	Multipoint	070034	24 Stevens St	Norwalk	CT	06850-385
114	Multipoint	300019	580 Court St	Keene	NH	03431-171
115	Multipoint	070015	21 Elm St	New Milford	CT	06776-291

If you scroll to the right, you can see the hospital's name, along with its bed count (*HRSAgeo_10*). After running this tool, you know that the closest hospital to the Millstone plant is hospital FID 101, The Lawrence & Memorial Hospital in New London, and it has 280 beds.

Since we now have a common attribute field between the two data layers (FID in Hospitals and NEAR_FID in our Nuclear plants, we could perform a table join to see them together in one layer.

10. Right-click on the **Nuclear_plantsUTM** layer and **choose Joins and Relates – Join** and fill in the box as follows:



11. Open the attribute table for the nuclear plants. Now, all the hospital information for the closest short term hospital to the nuclear plants has been added to the table!
12. Save your map!

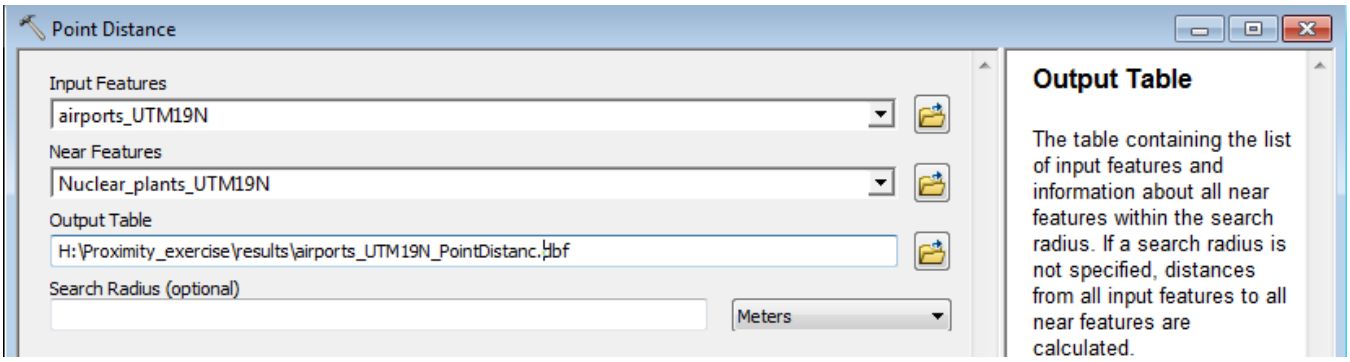
What if we want to know the closest hospitals outside the 12 mile zone? Can you think of a solution for this problem using tools you know? (Hint: one approach would be to select by location for all emergency hospitals within 12 miles, then switch selection to all other hospitals, then use NEAR on the selected emergency hospitals. You can find *Switch Selection* if you right click on the selected Emergency Hospitals, and go to *Selection – Switch Selection*.)

Point Distance Tool – Find the distance from all airports to all four nuclear plants

Since we may have to use multiple airports to respond to a crisis, we'd like to know how far EVERY airport in New England is to each of the nuclear plants. The **POINT DISTANCE** tool will calculate the distance from all points in one layer to all points in another layer.

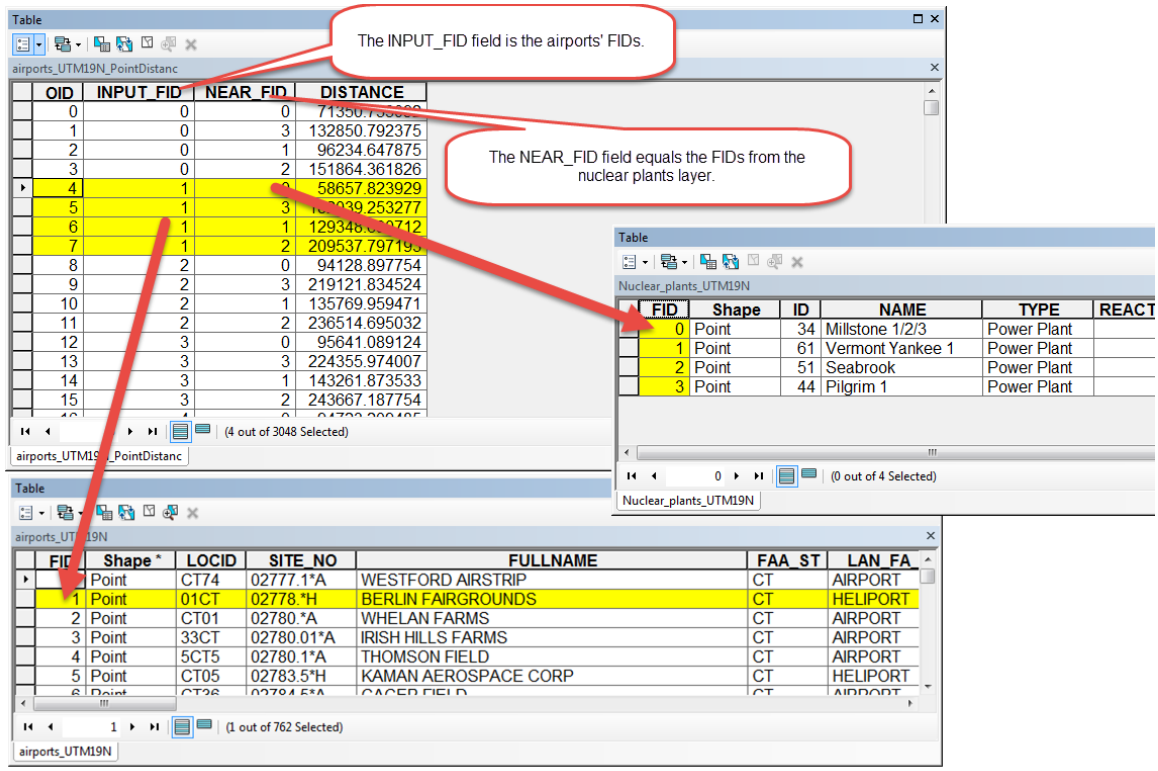
1. Clear any selections you have.

2. Go to **ArcToolbox → Analysis → Proximity** and double click on the **POINT DISTANCE** tool.
3. Fill in the dialog box as follows – note that the result will be a .dbf database table – remember the name and location!



4. Click OK and once is completed click **close** on the new window.
5. Open the new table which has been added to the bottom of the table of contents. You'll see the INPUT_FID which is the FID of the Airports and the NEAR_FID which is the FID of the Nuclear Plants (you can open those tables to see) – again the distance is in meters. See the graphic for guidance.

   Each input_FID (airports) repeats 4 times because it is measuring the distance to each of the 4 nuclear plants (near_FID).



From this new point distance table you could run a query in an emergency to find all the airports within a certain distance of a specific nuclear power plant. What would you need to do to find the distances of all airports to the Pilgrim 1 Nuclear Plant in Plymouth? Because each airport record is repeated four times, once for each of the four power plants, you'd first have to select out all the airport records for Near_FID = 3 (Pilgrim). Then you would export this to its own table (e.g., *Pilgrim_airport_distances)*. In that table the airport records are not repeated – that is there is a unique airport record on each row. Now the exported table can be joined back to the Airports table using the FID in Airports and the Input_FID from *Pilgrim_airport_distances* table.

Save your map again!

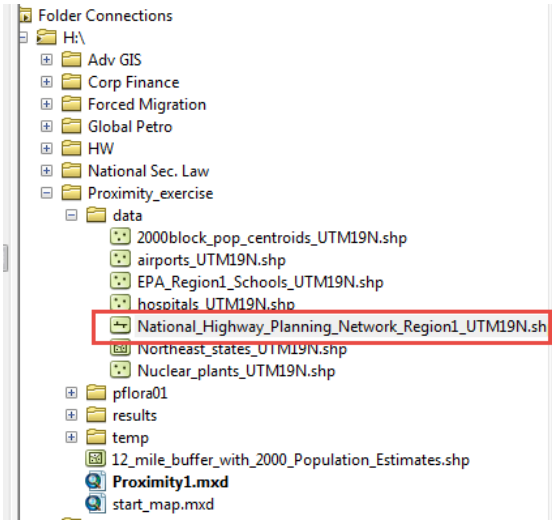
OPTIONAL: Network Analyst – Service Area Analysis - Visualize a 50 mile drive from each Nuclear Power Plant

We want to be able to visualize what response and relief resources are **within a 50 mile drive** of our nuclear power plants using a road network. The "as the crow flies" buffer (Euclidean distance) will not do this for us. But the **Network Analyst** *extension* has the functions we need.

This analysis is unfriendly in terms of the user interface but not difficult to do – here are the basic steps:

Create the network data set in ArcCatalog

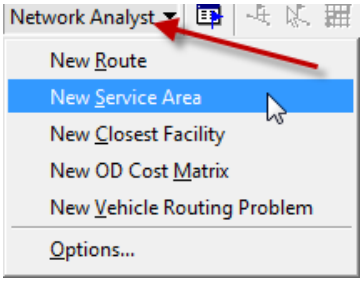
1. Enable the **Network Analyst** extension if not already enabled (**Customize → Extensions**).
2. In the Catalog, navigate to your proximity practice folder in your H drive and find the N**ational_Highway_Planning_Network_UTM19N** shapefile in the **Data folder.**



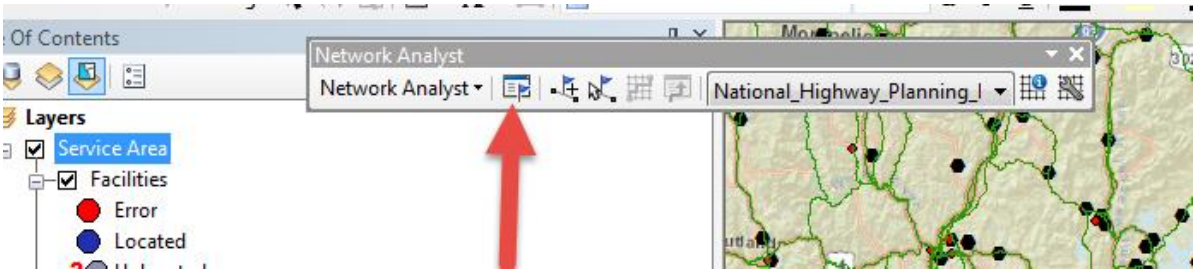
3. Right click on that data set and choose the option for **New Network Dataset.**
4. Accept all the defaults by clicking **Next**, except click **NO** for driving directions. Hit the **Finish** button, and finally say **Yes** to building the network dataset.
5. Also say **Yes** to adding it to your map.
6. Turn off the junction points layer (National_Highway_Planning_Network_Region1_UTM19N_Junctions) in your *Table of Contents*. Leave the Edges on – this is your network data set.

Performing the Service Area Analysis in ArcMap

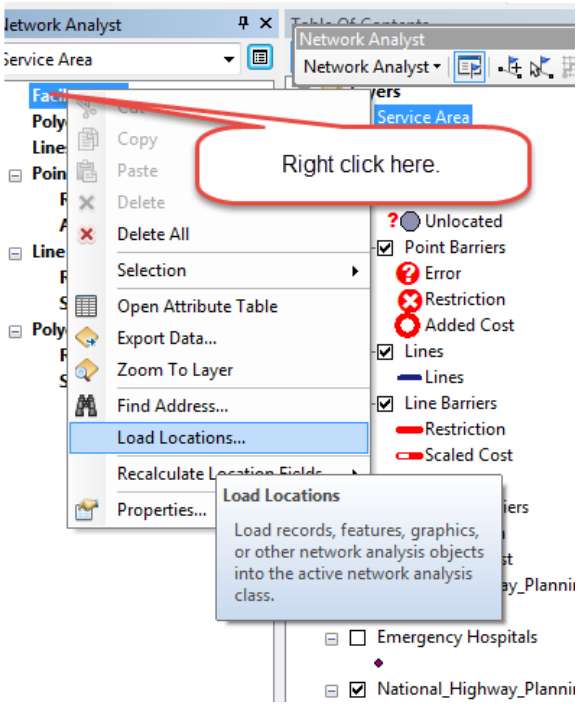
1. Go to **Customize → Toolbars** and check mark the **Network Analyst** toolbar.
2. From the **Network Analyst** toolbar choose *New Service Area*:



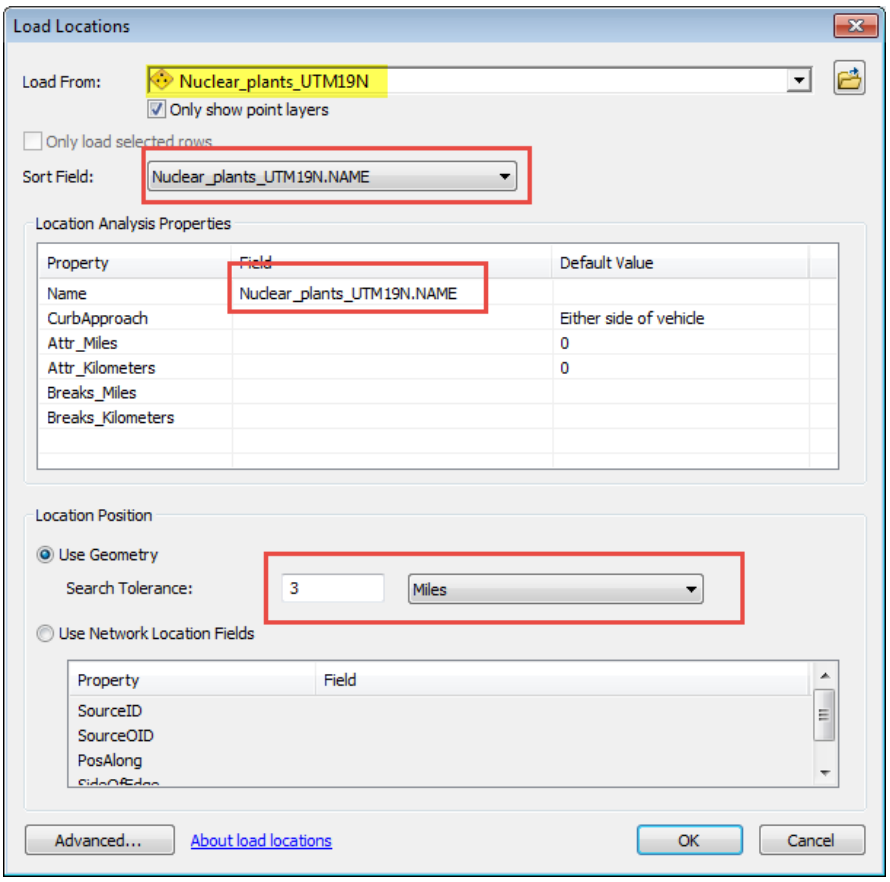
3. From the **Network Analyst** toolbar, click *on Network Analyst Window* (a new window to the left of the Table of Contents will appear).



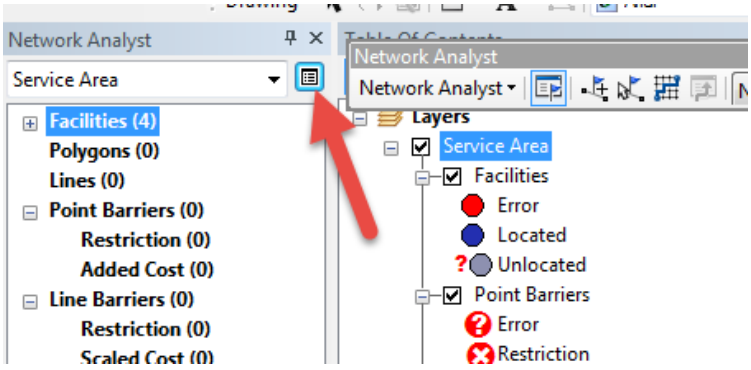
4. In the new **Network Analyst Window**, right-click on *Facilities* and choose *Load Locations* – these will be our Nuclear Power Plants:



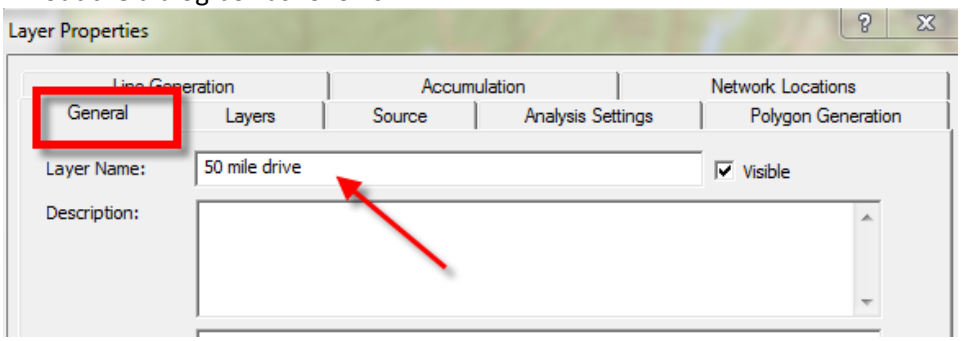
5. Fill out **the Load Locations** dialog box as follows:

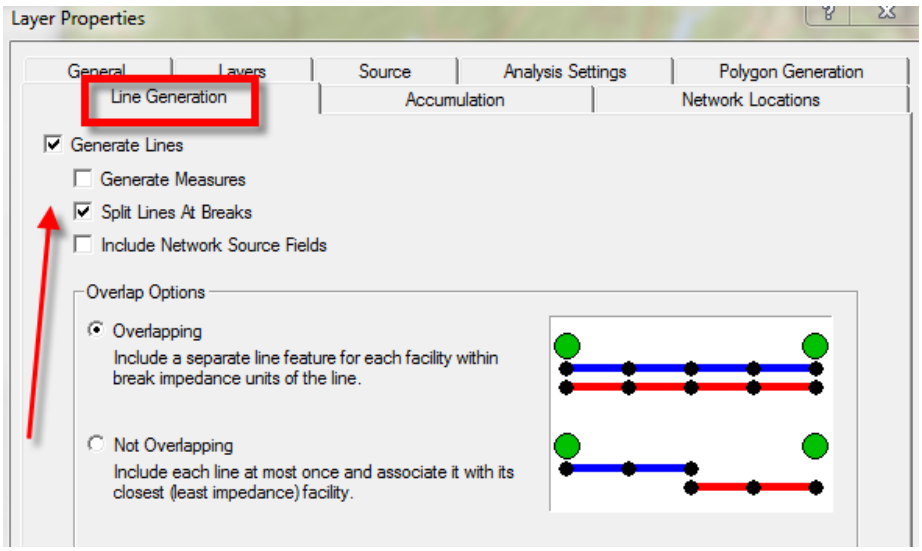


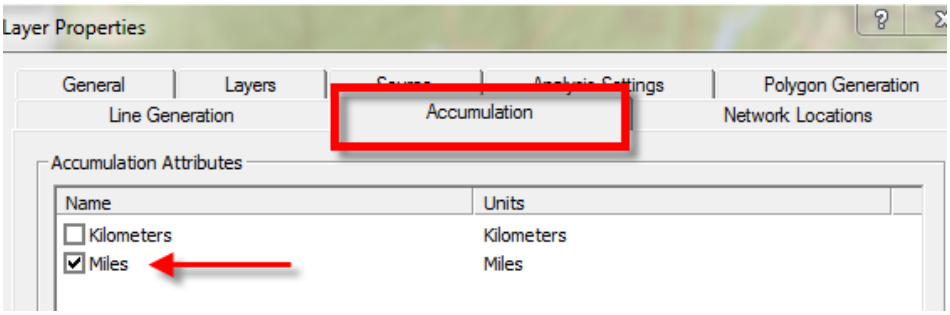
6. Press OK
7. You should have 4 facilities located (the four nuclear plants). Click on the **Service Areas Properties** box:

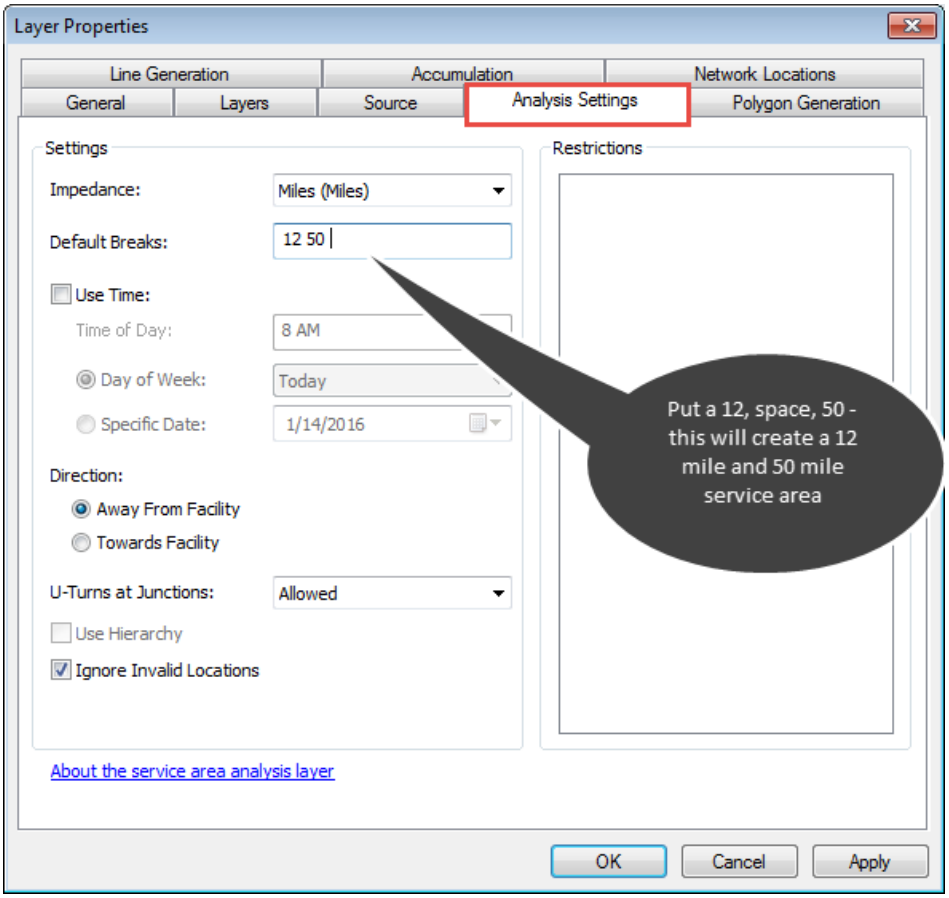


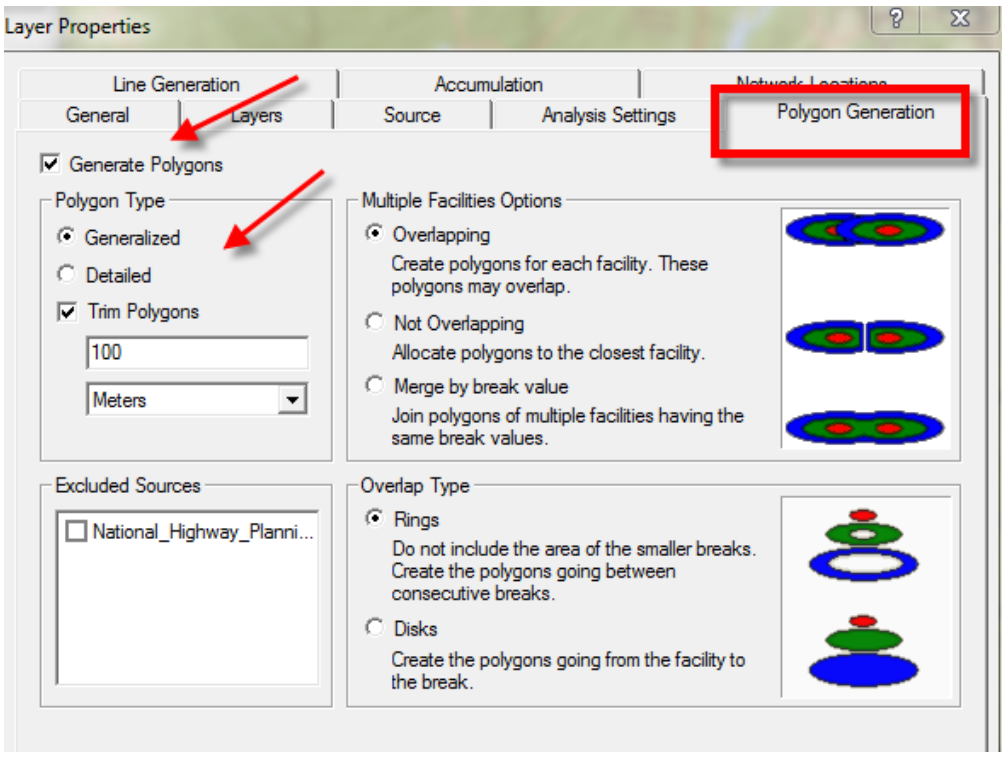
8. Fill out the dialog box as follows:



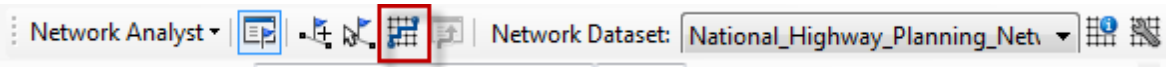

Layer Properties
General
Layers
Source
Analysis Settings
Polygon Generation
Line Generation
Accumulation
Network Locations
Generate Lines
Generate Measures
Split Lines At Breaks
Include Network Source Fields
Overlap Options
Overlapping
Include a separate line feature for each facility within break impedance units of the line.
Not Overlapping
Include each line at most once and associate it with its closest (least impedance) facility.


Layer Properties
General
Layers
Polygon Generation
Line Generation
Accumulation
Network Locations
Accumulation Attributes
Name
Units
Kilometers
Kilometers
Miles
Miles

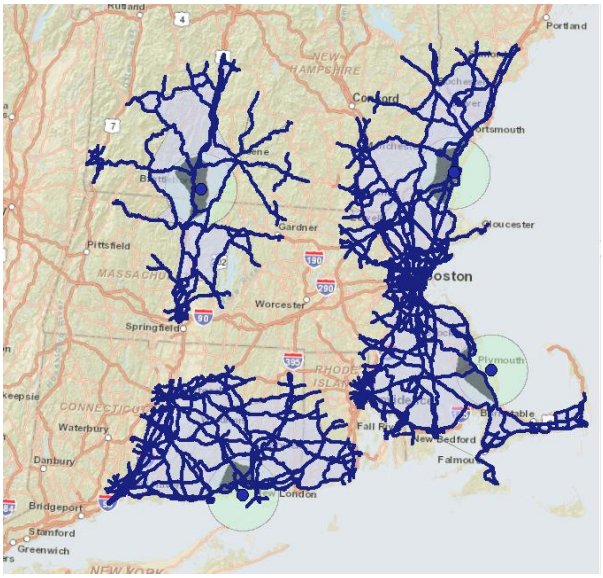

Layer Properties
Line Generation
Accumulation
Network Locations
General
Layers
Source
Analysis Settings
Polygon Generation
Settings
Impedance:
Miles (Miles)
Default Breaks:
12 50
Use Time:
Time of Day:
8 AM
Day of Week:
Today
Specific Date:
1/14/2016
Direction:
Away From Facility
Towards Facility
U-Turns at Junctions:
Allowed
Use Hierarchy
Ignore Invalid Locations
Restrictions
Put a 12, space, 50 - this will create a 12 mile and 50 mile service area
About the service area analysis layer
OK
Cancel
Apply



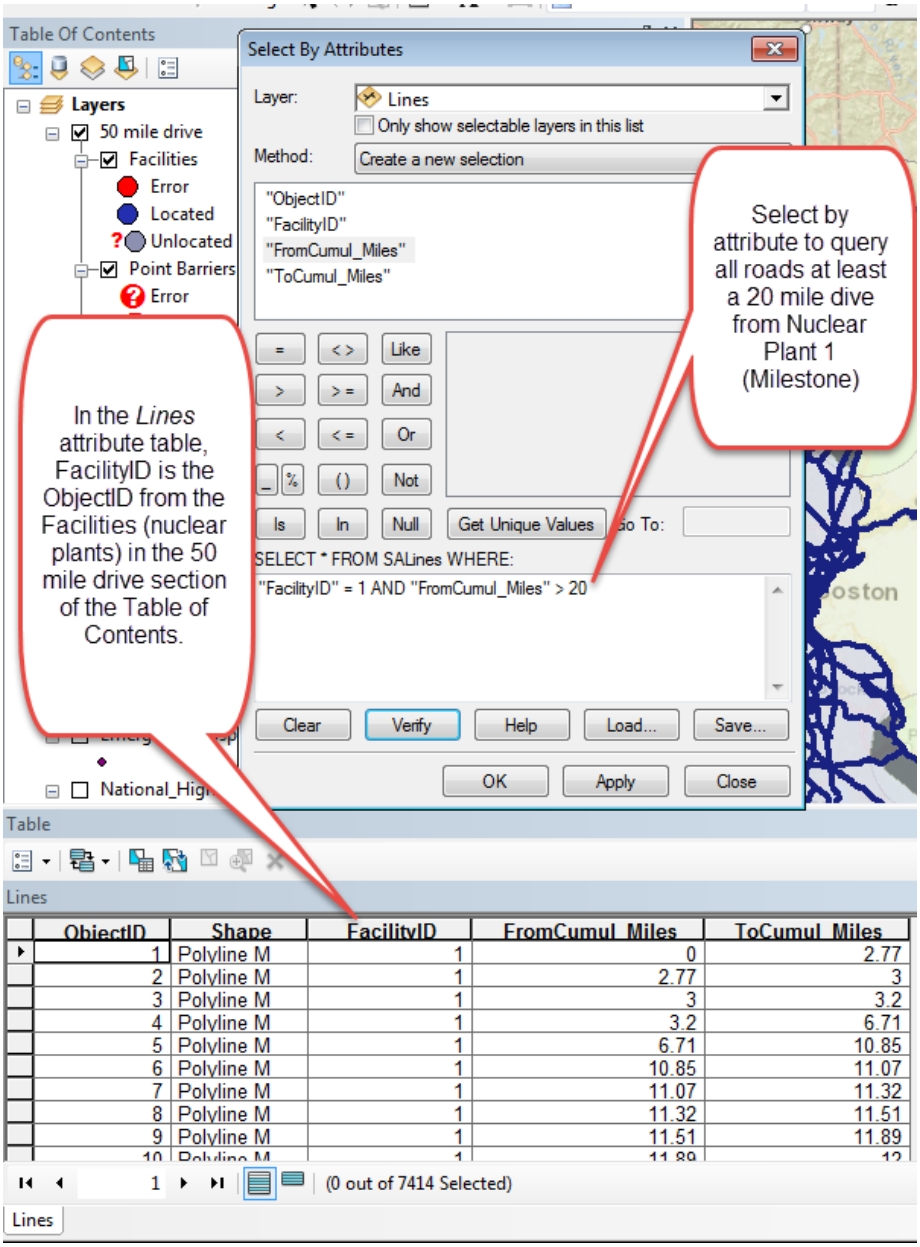
9. Click OK. Nothing happens yet!
10. Now click on the **SOLVE** icon



11. Your map should now look something like this – the purple roads and light purple zone is within a 50 mile drive of a Nuclear Plant.



12. You can turn on hospitals, schools or airports to visualize where potential resources are within these zones. Or you can select them by whether they are inside the zones, or close to roads within the zones, etc.
13. Explore the attribute tables for **Lines** in the **50 mile drive** area of the *Table of Contents* – note you can do things like select for all roads that are at least a 20 mile drive from a particular facility:



You could continue this analysis with tools you know. For example, what if we wanted to find all the high schools that are within a half mile of our selected highway lines from the Millstone plant above so that they could serve as relief centers in the case of a problem?

If you turn on your 12 and 50 mile multi-ring buffer – note that being 50 miles away by road is not the same as being 50 miles away in straight line distance!

The service area analysis is more typically used to find things like the streets within a walkable distance (e.g., ¼ mile) or a driving distance (e.g., 5 miles) of a service like a store or hospital.

That's enough for now. But we hope you see that using these kinds of tools you could manage a true geographic INFORMATION system that can help respond in an emergency and to plan for the unexpected.