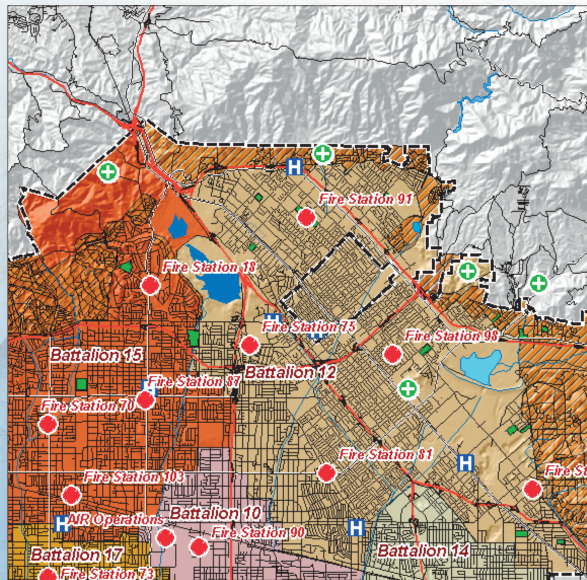
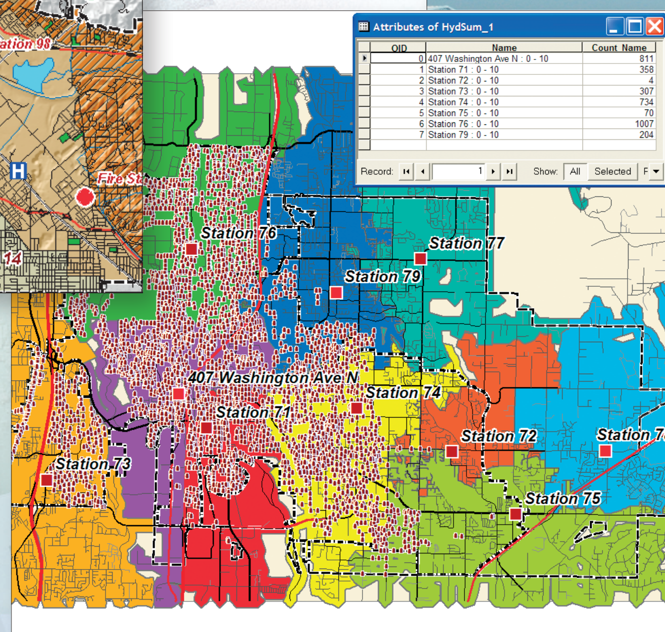
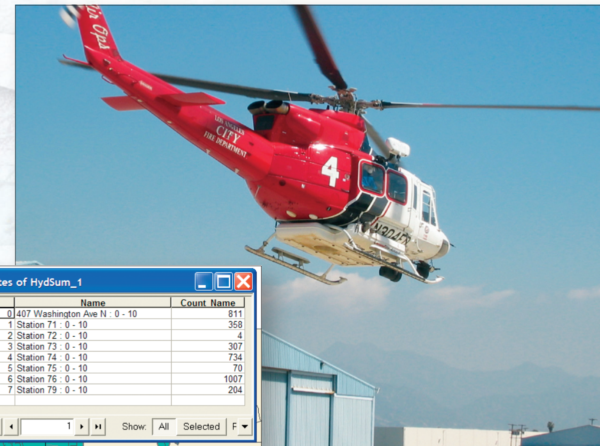
GIS Best Practices

Fire Mapping with ArcGIS







November 2009

ESRI

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

Modeling GPS Data

Captured on the Fly

By Mike Price and Amy Fox, Entrada/San Juan, Inc.

What You Will Need

- ArcGIS 9.x (ArcView, ArcEditor, or ArcInfo license level)
- Evaluation copy of XTools Pro downloaded from www.xtoolspro.com/download
- Sample dataset from *ArcUser Online*
- WinZip or other similar zipping utility

This tutorial replicates part of the Los Angeles Fire Department (LAFD) Air Operations (Air Ops) data processing workflow. It demonstrates how to use rapidly calculated longitude and latitude values for flight path points, convert selected points into a closed polygon, and calculate perimeter and area for a selected flight polygon using ArcGIS 9.1 and a third-party ArcGIS extension, XTools Pro. **For background information on the development of this workflow, see the accompanying article, "Tragedy to Triumph."**

This tutorial creates the point flight path and derives an incident polygon from data collected during a training flight by LAFD Air Ops.

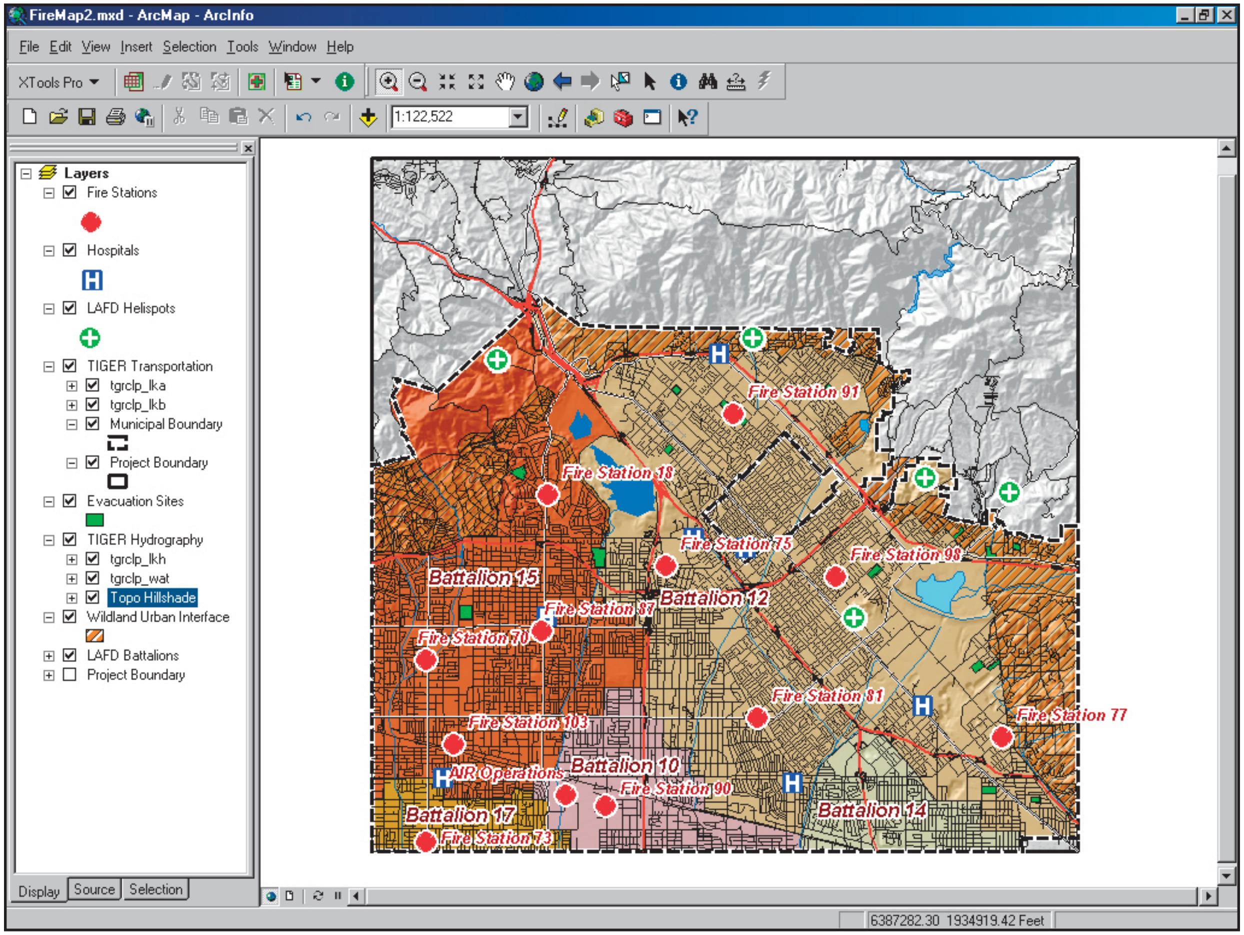
Getting Started

Visit *ArcUser Online* (www.esri.com/arcuser) and download the zipped archive containing the data for this exercise. Unzip the archive and open ArcCatalog to view the files. The archive creates a parent directory named FireMap that contains two subdirectories, one for shapefiles and one for grid files. The grid files are registered in California State Plane North American Datum of 1983 (NAD83) Zone V U.S. Feet. Most shapefiles are registered in California State Plane with the exception of the training data file TR1_060316_1122 that was created in the World Geodetic System 1984 (WGS84) geographic coordinate system.

Next, visit Data East's download portal at www.xtoolspro.com/download and obtain a 30-day evaluation copy of the XTools Pro extension. Table 1 summarizes XTools Pro features and functions. Many basic functions are available in the free download while additional functionality can be purchased online. This tutorial uses these three free functions:

- Add XYZ Coordinates
- Make One Polygon from Points
- Calculate Area, Perimeter, Length, Acres and Hectares

After downloading and extracting the XTools Pro archive, navigate to the directory containing the XTools Pro 3.2.0 folder and double-click the setup.exe file. After working through the setup wizard, verify the program has been installed by navigating to \ProgramFiles\DataEast\XToolsPro3. Restart ArcMap. Enable the XTools Pro extension by choosing Tools > Extensions from the Standard menu and checking the box next to the XTools Pro extension. Close the Extensions dialog box. In the Standard menu, choose View > Toolbars and add the XTools Pro toolbar.



Add the shapefiles and hillshade to create a basemap for the training data.

Building a Basemap

1. Start ArcMap and open a new map document.

2. Navigate to FireMap\SHPFiles\CASP835F\ and add the Project Boundary LYR file to the Data Frame. If the data connection in the layer file is broken, right-click Project Boundary's name in the table of contents (TOC), choose Data > Set Data Source, and navigate to FireMap\SHPFiles\CASP835F\Clippol1.

3. Open the Data Frame properties and verify that the Project Boundary data has set the coordinate system to CA State Plane NAD83 Zone V US Feet. Click the General tab and rename the Data Frame CA State Plane NAD83 Zone V US Feet.

4. Load the remaining layer files stored in the FireMap\SHPFiles\CASP835F folder. Each LYR file should load the appropriate shapefile or grid and associate it with the desired thematic legends. Repair any broken links by right-clicking on the layer file in the TOC, selecting Data > Set Data Source, navigating to FireMap\SHPFiles\CASP835F\, and selecting the shapefile corresponding to the layer file.

5. Add the Topo Hillshade layer stored in FireMap\GRDFiles\CASP835F and arrange the TOC data layers in the following order (top to bottom):

    1. Fire Stations
    2. Hospitals
    3. LAFD Helispots
    4. TIGER Transportation
    5. Municipal Boundary
    6. Project Boundary
    7. Evacuation Sites
    8. TIGER Hydrography
    9. Topo Hillshade (transparency set to 50 percent)
    10. Wildland Urban Interface (no forward slash between Wildland and Urban!)
    11. LAFD Battalions (labeled)

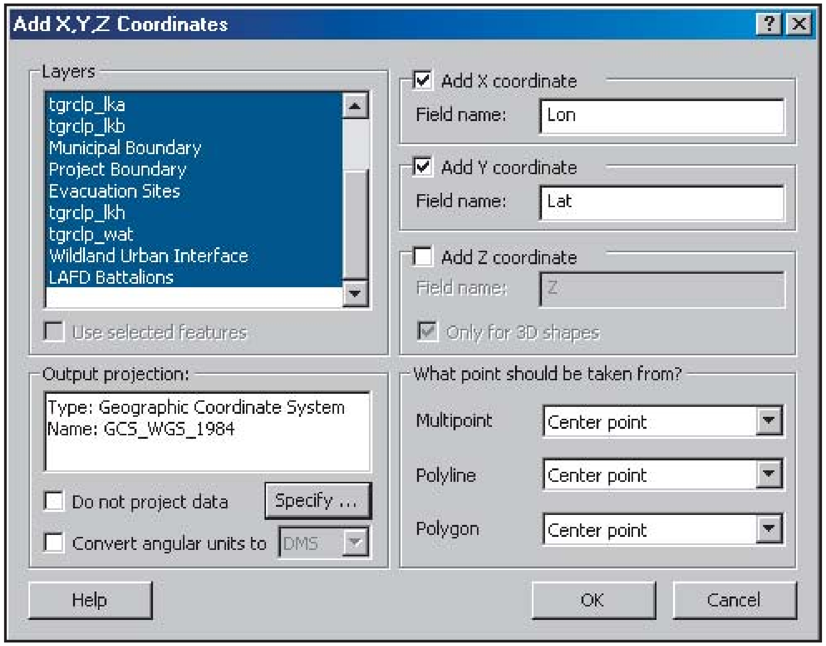
6. Save the map in the FireMap folder and name it FireMap1. Become familiar with the data layers and check out the attributes for each.

Loading Flight Path Data

With the basemap created, the GPS data can be added to the map document. This data was gathered during a training flight in northern Los Angeles County on March 16, 2006. Navigate to FireMap\SHPFiles\LatLon84 and load TR1_060316_1122, a single point shapefile. Its name, TR1_060316_1122, indicates that it was collected during a training flight by Airship 1 on March 16, beginning at 1122 (i.e., 11:22 a.m. Pacific standard time). An ArcMap dialog box will warn that the data was created in another projection and will be transformed to California State Plane. Inspect this data and its attribute table. The flight began at Air Ops headquarters at the Van Nuys Airport, then traveled east over the San Gabriel foothills.

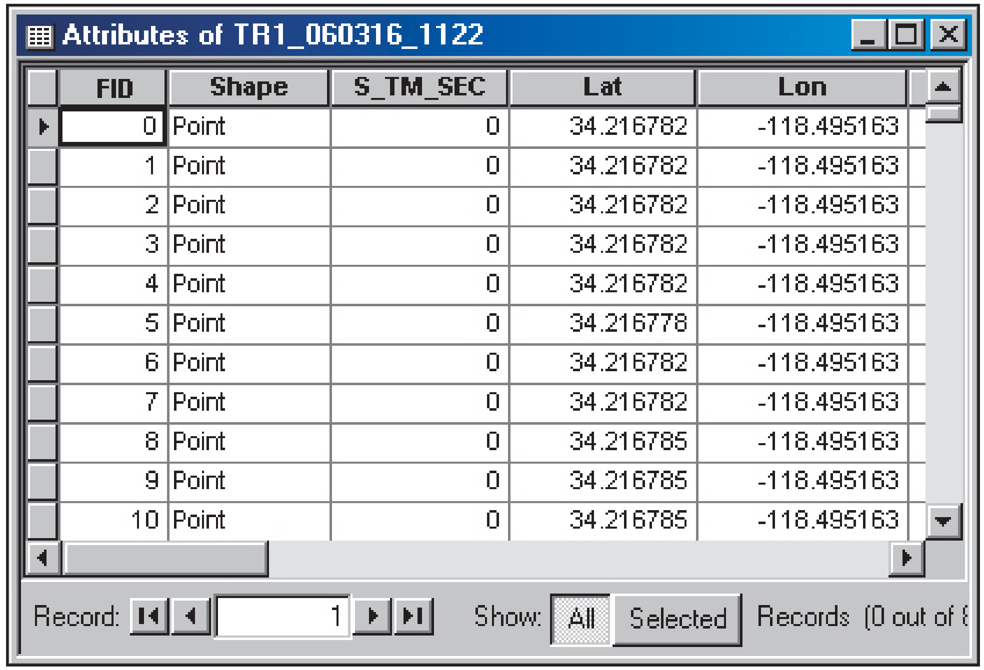
Calculating Longitude and Latitude Values for Flight Points

XTools Pro will be used to calculate the X- and Y-coordinates for the flight paths. In the TOC, right-click the TR1_060316_1122 point layer and choose Open Attribute Table. Notice that the Lat and Lon fields contain zero values. These fields will be updated with coordinates in decimal degrees WGS84.



1. Click the XTools Pro toolbar drop-down arrow and select Table Operations. Select Add X,Y Coordinates. In the Add X,Y,Z Coordinates dialog box, hold down the Shift key and highlight the TR1 set. Check the Add X Coordinate box and change the field name to Lon. Check the Add Y Coordinate box and change the field name to Lat. Uncheck the Z Coordinate box and leave the point drop-down boxes (e.g., Multipoint, Polyline, and Polygon) with the default value.
2. Click Specify. A new spatial reference box will appear. Click Select and double-click Geographic Coordinate Systems. In the World folder, select the WGS 1984.prj definition. After selecting this coordinate system, click Add, then click OK.

3. In the Add X,Y,Z Coordinates box, click OK. Click Yes to overwrite existing Lon and Lat fields in the attribute tables. Verify that each attribute table has a new set of latitude and longitude coordinates. Notice that the decimal precision carries six characters to the right of the decimal. At this latitude, this represents precision of less than one meter. Save the project.



FID	Shape	S_TM_SEC	Lat	Lon
0	Point	0	34.216782	-118.495163
1	Point	0	34.216782	-118.495163
2	Point	0	34.216782	-118.495163
3	Point	0	34.216782	-118.495163
4	Point	0	34.216782	-118.495163
5	Point	0	34.216778	-118.495163
6	Point	0	34.216782	-118.495163
7	Point	0	34.216782	-118.495163
8	Point	0	34.216785	-118.495163
9	Point	0	34.216785	-118.495163
10	Point	0	34.216785	-118.495163

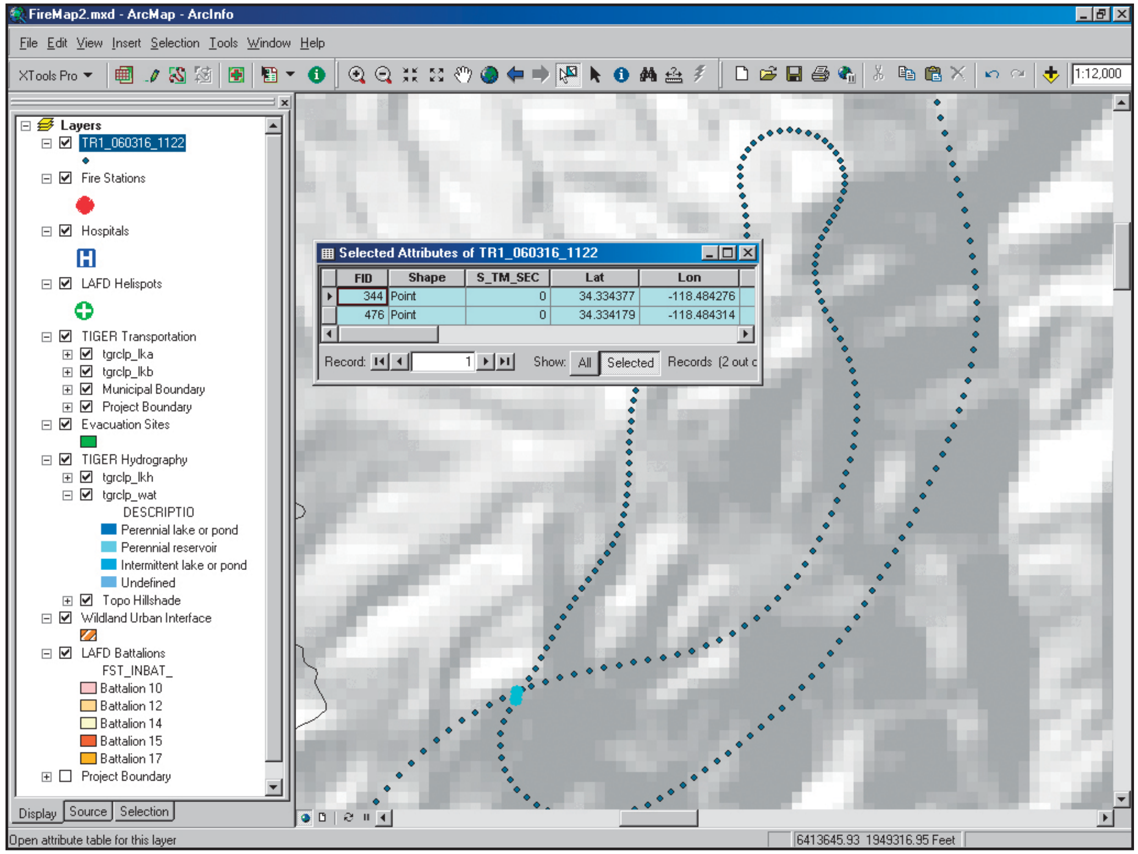
After calculating the X- and Y-values, notice that the decimal precision carries six characters to the right of the decimal. At this latitude, this represents precision of less than one meter.

Measuring Flight Paths and Calculating Ground Speed

Zoom into the map just north of where the flight path crosses above Fire Station 87 so that the map scale is 1:5,000. Select 17 points north of the station that represent one-half mile of flight line. Looking at this data, how fast was the helicopter flying? *(Hint: Measure the distance between point 0 and point 16. Each point represents one second of air time. Traveling one-half mile in 16 seconds represents a ground speed of 112.5 mph, or slightly less than two miles per minute.)*

Retracing the Flight Path

Reset the map scale to 1:12,000 and pan north along the flight points to the loop in the flight path (i.e., where the flight path crosses itself). It traces the perimeter of an area of interest. The UltiChart navigation unit in the helicopter accurately captured this boundary. Using the Select Features tool, capture the two points just outside the closed loop. Open the Attribute Table and click Show: Selected Records to display only those features (FID points 344 and 476). Confirm that the airship required just over two minutes to fly this perimeter. *Did you notice that the helicopter was flying in a counterclockwise direction?* Because the pilot sits in the right seat, this perimeter path was guided by the navigator in the left seat.



The flight loop shows an area of interest. Using the Select Features tool, capture the two points just outside of the closed loop. Open the attribute table and click on Show: Selected Records to display only those features (FID points 344 and 476).

Creating a Closed Polygon from Points with XTools Pro

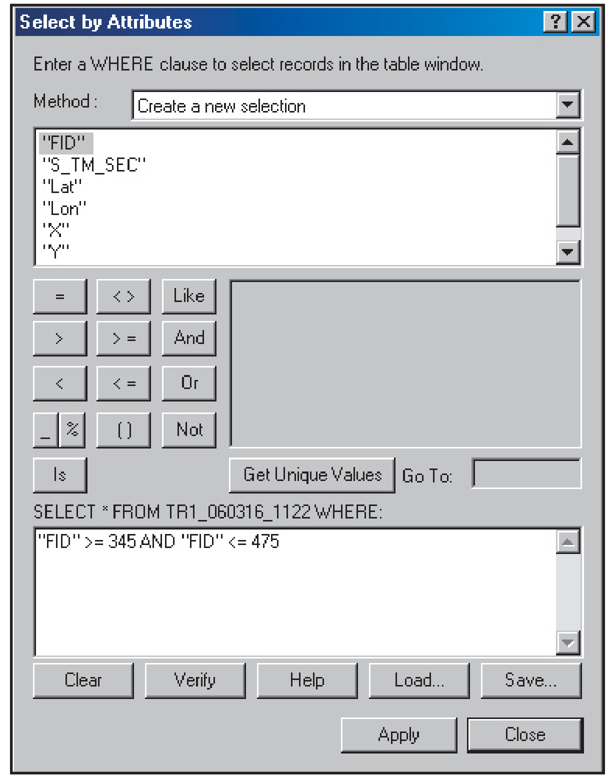
Boolean logic can be used to define the polygon area of the flight path by selecting the points that initialize the loop and writing a query to limit the shape of the flight path to these points. *Can you determine where the loop originates and ends?* Note the lowest and highest FID numbers of the two points inside the loop are 345 and 475.

1. In the Attribute Table, click the Options drop-down arrow and choose Select by Attributes.

2. In the Select by Attributes dialog box, write this query: "FID" >=345 AND "FID" <=475. Click Apply and close the Select by Attributes dialog box. Close the Attribute Table. This selects 131 points that are arranged in a ghostlike loop.

3. A polygon can be created from this poly/point selection. Verify that TR1_060316_1122 is the active layer in the TOC. Click the XTools Pro drop-down arrow on the XTools Pro toolbar and select Feature Conversion. Choose Make One Polygon from Points.

4. In the Output storage window, click the browse button and navigate to the SHPFiles\LatLon directory. In the Name New Feature Class box, highlight TR1_060316_1122 by clicking one time. Edit the source name by adding an underscore and the suffix P1 (_P1). The point layer TR1_060316_1122 becomes a polygon named TR1_060316_1122_P1. Click Save and OK. ArcMap adds the new polygon layer to the top of your table of contents, and it will be given a default color. Select a bright color for the polygon. Turn off the original TR1 layer by unchecking the box. Clear all selected features; choose Selection > Clear Selected Features. Save the project.

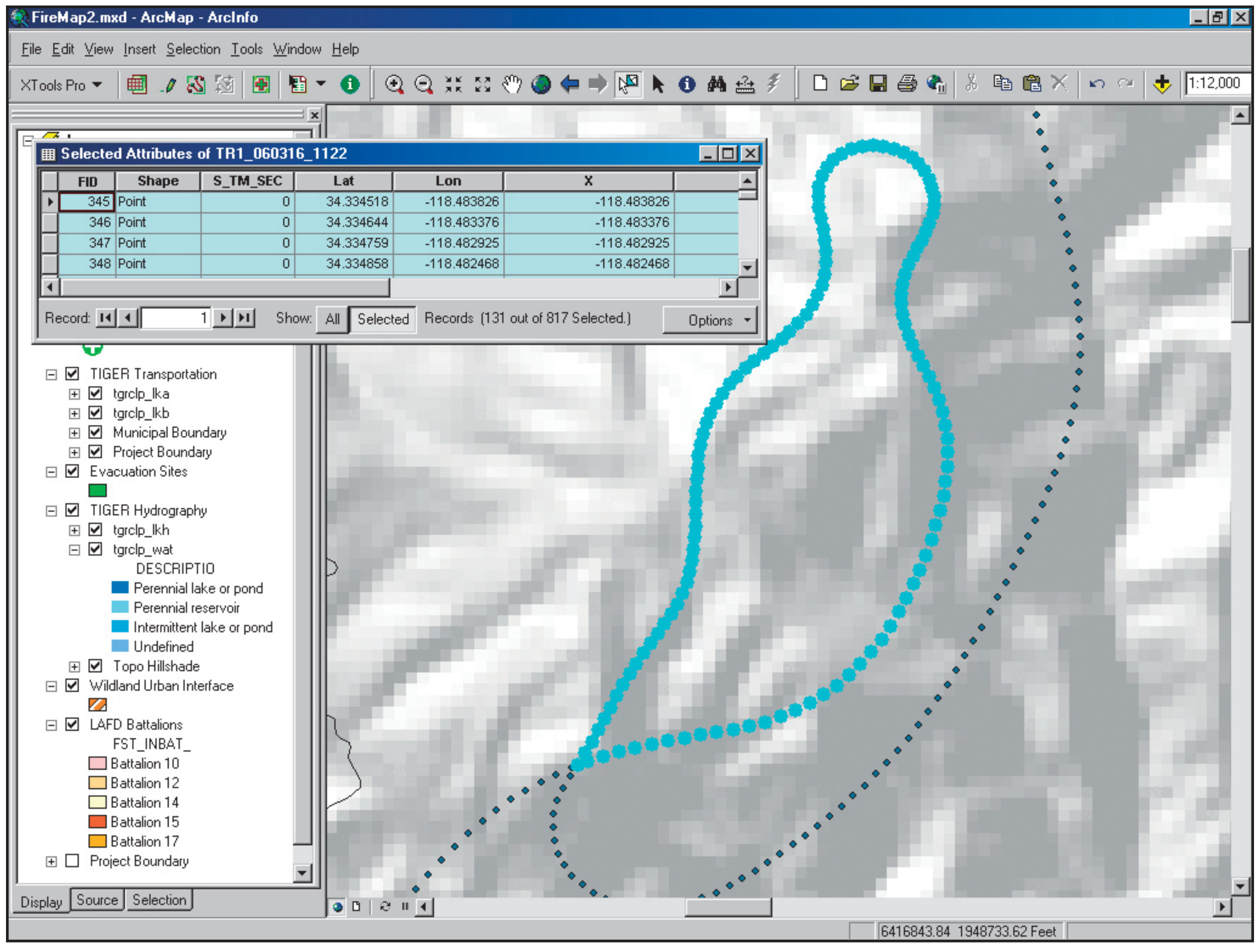


Choose the Select by Attributes dialog box, and use a query to select all the points in the loop.

Calculating Perimeter and Area

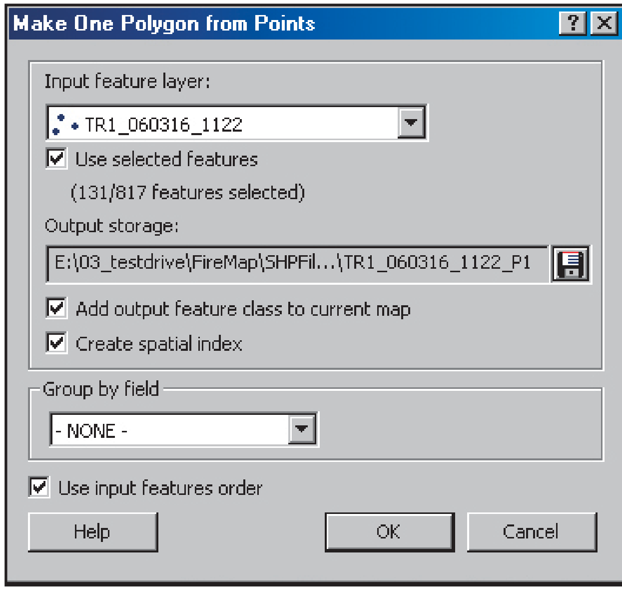
1. Right-click TR1_060316_1122_P1 and choose Zoom to Layer. Open this layer's attribute table. Move the table in the lower left part of the display.

2. Click the XTools Pro drop-down arrow on the XTools toolbar. Choose Select Table Operations > Calculate Area, Perimeter, Length, Acres and Hectares. In the Calculate window, locate Output Projection and click Specify.

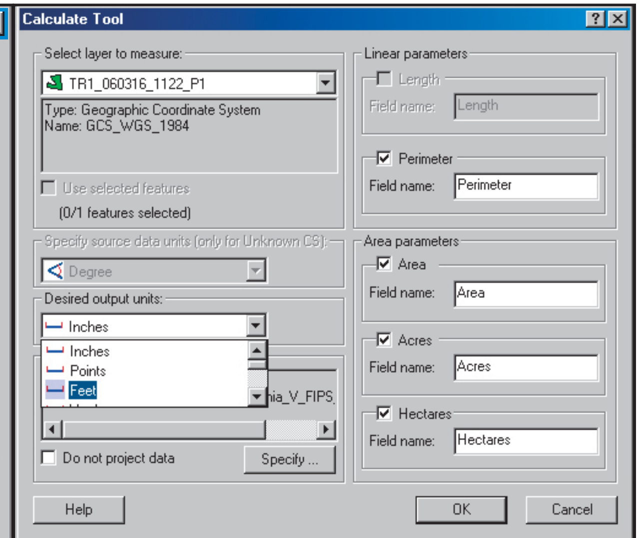


Click the XTools Pro drop-down arrow on the XTools toolbar and choose Select Table Operations > Calculate Area, Perimeter, Length, Acres and Hectares.

3. Click the Specify button in the Spatial Reference Properties dialog box and choose Projected Coordinate Systems. Navigate to State Plane, then NAD 83 (Feet), and select NAD 83 StatePlane California V FIPS 0405 (Feet).prj. Click Add, OK, and OK. Change desired output units to Feet. ***This is a critical and easy to miss step!*** Accept all other default selections and click OK. The attributes now include measurements. Minimize the Attribute Table and save the project.



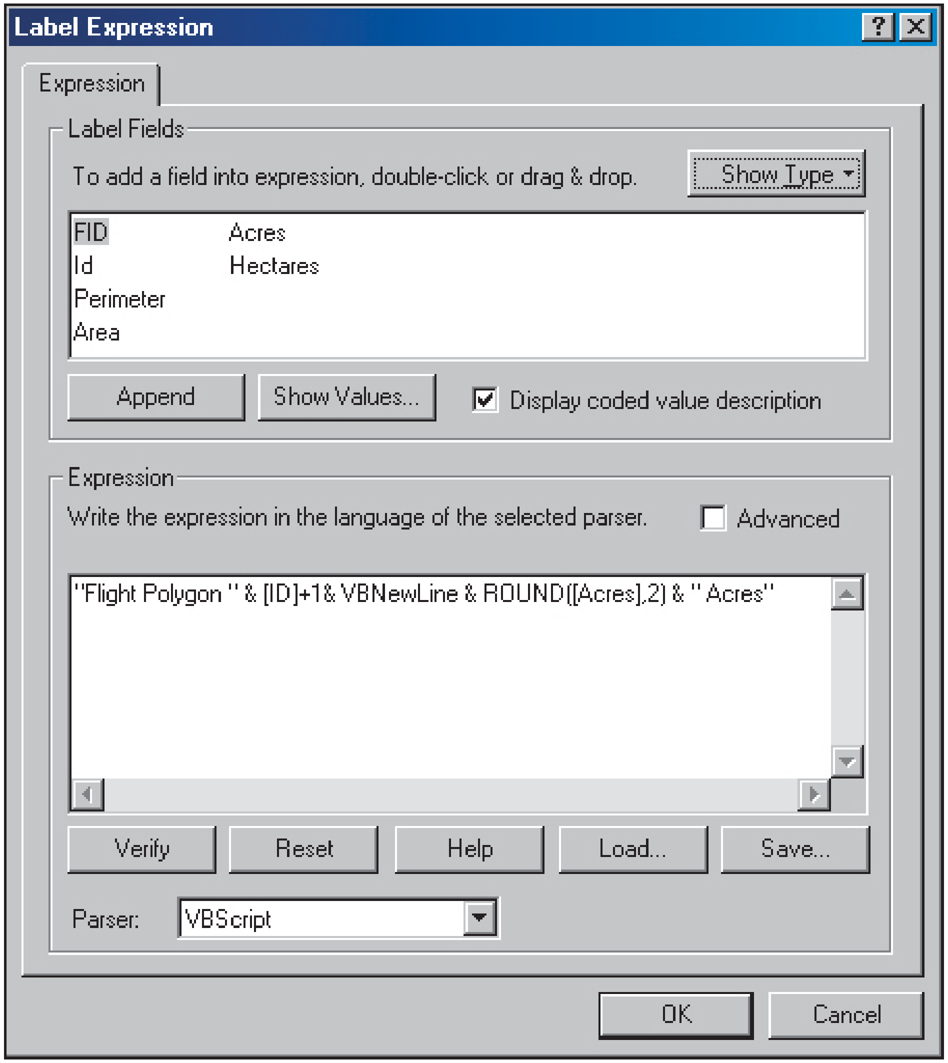
A polygon can be created from this poly point selection.



When using the Calculate Area, Perimeter, Length, Acres and Hectares function in XTools Pro, be sure to change the input units to feet.

Validating and Labeling the Polygon

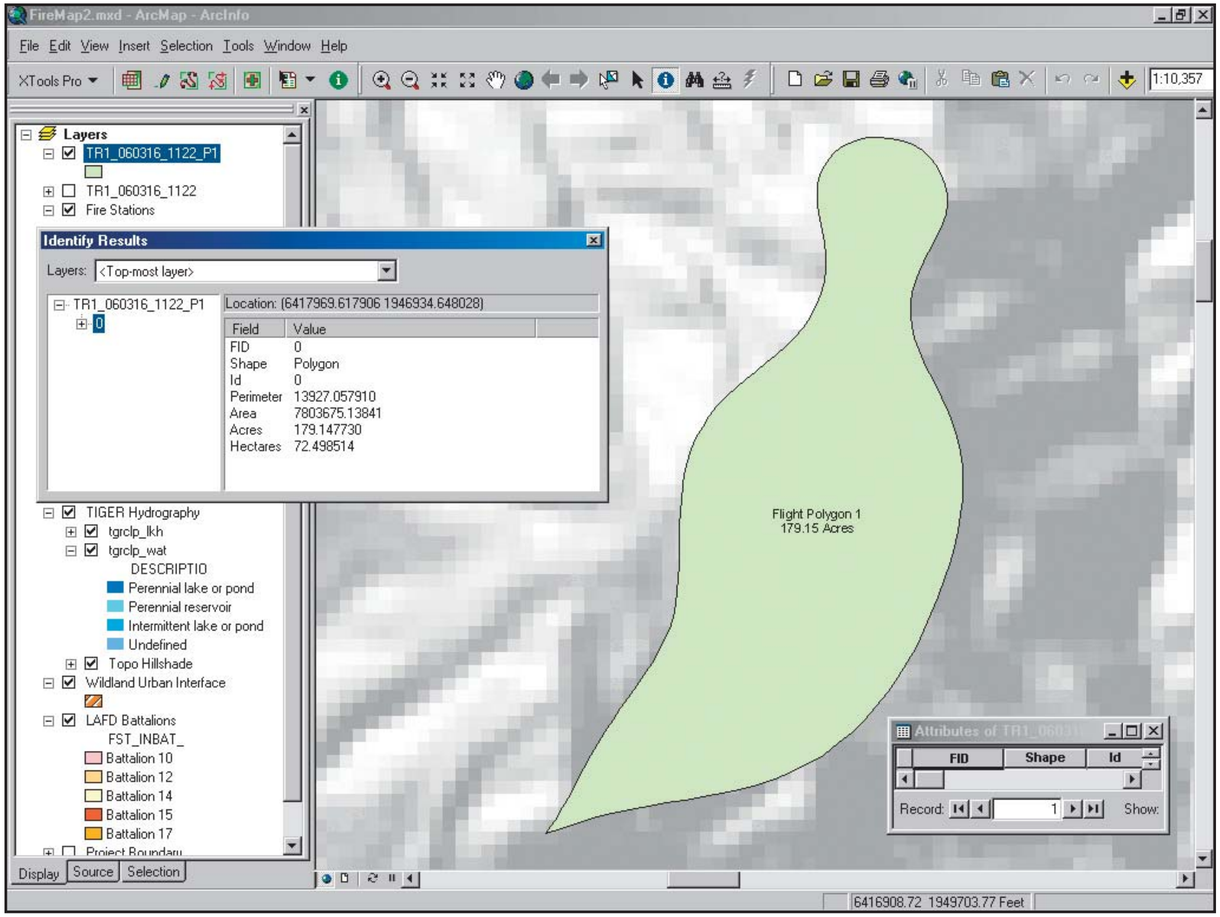
1. Use the Identify tool to verify that the new polygon has an area of 179.147730 acres. To create a label, right-click TR1_060316_1122_P1 and select Properties. Choose the Labels tab and click the Expressions button. In the Expressions box, type: "Flight Polygon" & [ID]+1& VBNewLine & ROUND([Acres],2) & " Acres" Be certain to insert a leading space before the text " Acres". Click Verify to confirm the expression and label format. Click OK twice to exit both dialog boxes.



Use an expression to label the new polygon.

2. In the Layer Properties dialog box, click Symbol. In the Symbol Selector dialog box, click Properties. Click the Mask tab and set the Halo to 2.00 points. Click OK. In the Symbol Selector dialog box, choose Arial font at 18 points, bold, italic. Click OK.

3. In the Layer Properties dialog box, check Label features in this layer. Click OK and apply the new label properties to the map. Verify that the label was successfully created.



The finished flight polygon is labeled with the area of the polygon.

Summary

This tutorial creates the point flight path and derives an incident polygon from data collected during a training flight by LAFD Air Ops. LAFD's mapping program is growing rapidly. Steven Robinson, the program's creator, envisions the day when a captured polygon, merged with current demographic information, will be transferred to incident managers in real time. When processed by reverse 911, citizens at risk may be quickly alerted. Through careful program design, staff training, current data development, and support from LAFD management and technology providers, Robinson's dream is within reach.

This tutorial replicates part of the Los Angeles Fire Department (LAFD) Air Operations (Air Ops) data processing workflow. Rapidly calculated longitude and latitude values for flight path points are converted into a closed polygon and the perimeter and area calculated.

Tragedy to Triumph

Pilot's Vision Leads to Onboard State-of-the-Art Mapping

In March 1998, three Los Angeles city firefighters and a young girl being transported to a hospital were killed in a helicopter crash in the Griffith Park area of Los Angeles, California.

Steven Robinson, the helicopter's pilot, was one of two crew members who survived the crash. Despite several years of rehabilitation, Robinson was unable to return to active flight status. However, instead of leaving the Air Operations (Air Ops) service, Robinson developed and implemented a state-of-the-art data capture, analysis, and mapping program that provides the Los Angeles Fire Department (LAFD) airships with high-quality current maps onboard and a current common operating picture (COP) to emergency managers and responders for a wide range of emergency and nonemergency events.

When Robinson discovered that the GPS-based onboard navigation system for the department's helicopter fleet accurately captured an airship's position during every second of flight, he envisioned a process for carefully tracing and recording the perimeter of emergencies and other events such as wildland fires, hazmat accidents, natural disasters, and public gatherings.

In 2002, Robinson approached ESRI to request assistance with mapping technology, data development, and real-time mapping. Russ Johnson, ESRI's public safety solutions manager, recognized the value of Robinson's idea. With technical assistance from ESRI and hardware donated by Hewlett-Packard, Robinson's helicopter mapping program literally took off. As the program has grown, it has been recognized by the City of Los Angeles, neighboring communities, and adjoining counties. Robinson received many more requests for mapping services than he could handle. He decided to develop and support a standard data capture workflow, template-based incident mapping, and a training program that would empower helicopter pilots, flight medics, and firefighters to participate in aerial data collection and emergency mapping.

LAFD Air Ops began using an ArcGIS extension called XTools Pro to quickly and easily manage and model flight path points. Originally developed in the mid-1990s by the Oregon Department of Forestry, XTools for ArcView 3.x gained broad acceptance among wildland fire mappers and natural resources GIS professionals. After the release of ArcGIS 8, XTools was acquired by Data East, LLC, an authorized business partner of ESRI Russia's distributor Data+. Data East ported XTools to ArcGIS 9 and sells XTools Pro 3.2 through its Web site at www.xtoolspro.com.

In early 2006, ESRI sponsored a program to define a standard workflow and train Air Ops mapping staff. Project requirements included capturing high-quality GPS points and rapidly transferring these points to a modeling computer. First, the GPS points are managed and filtered to map flight paths and incident boundaries. Next, the points are converted to polygons and perimeters and those areas are calculated. The map elements are then posted in a standard map template for plotting and delivery to incident managers.

Acknowledgments

The authors thank Los Angeles Fire Department pilot Steven Robinson, Air Operations Battalion Chief John Buck, and the entire helicopter crew for their support and interest. Special thanks are also extended to ESRI, IBM/Lenovo, and HP for providing software, hardware, and program technical support.

(Reprinted from the July–September 2006 issue of *ArcUser* magazine)

Got It Covered

Modeling Standard of Cover with ArcGIS Network Analyst 9.2

What You Will Need
- ArcGIS 9.2 (ArcInfo, ArcEditor, or ArcView license)
- ArcGIS Network Analyst 9.2 extension
- Sample dataset downloaded from *ArcUser Online*

By Mike Price, Entrada/San Juan, Inc.

Throughout much of the United States, the Insurance Services Office (ISO) maps fire station locations and measures response capabilities based on transportation systems, equipment, personnel, and other factors. It assesses and reports on the level of protection provided to member insurers.

The following exercise uses the new ArcGIS Network Analyst 9.2 extension to map and model time- and distance-based response around existing and proposed fire stations throughout King County Fire District 37. The exercise maps 1.5 mile ISO fire hydrant deployment, five-minute distribution, eight-minute concentration, and optimal time-based response for all stations.

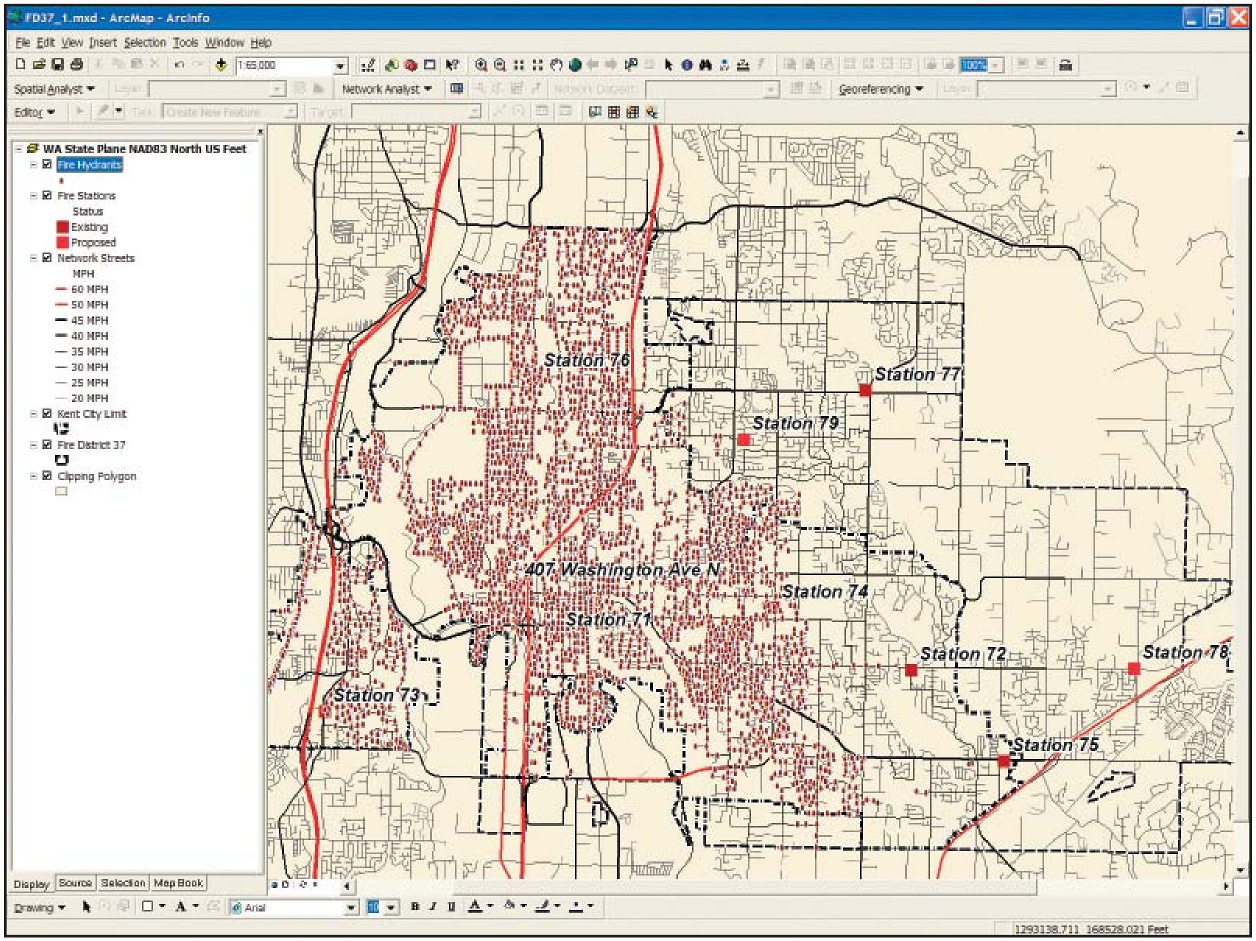
ArcGIS 9.2 and the new Network Analyst extension provide many enhancements and improvements for public safety modelers. Geometric calculations within attribute tables are easier to perform. The new Network Dataset accommodates complex turn rules and multimodal travel. The service area polygon solver incorporates buffered trimming around outlying paths. A new optimal solver creates coincident polygons using time or distance to help define station service areas. This exercise introduces these enhanced features. **For more information, see accompanying article, "Developing a Standard of Cover."**

Starting the Exercise

Visit the *ArcUser Online* Web site at www.esri.com/arcuser and download the sample dataset for this tutorial.

1. Unzip the archived sample dataset at or near the root directory of a local drive. The archive creates a folder called FD37 with a SHPFiles folder, containing a subfolder called WASP83NF.

2. Open ArcCatalog and explore the sample data in WASP83NF. It consists of six shapefiles and six associated layer files. Link the Layer files to the source shapefiles by right-clicking on each one in the table of contents, accessing the Properties dialog box, selecting Data > Set Data Source, and choosing the shapefile referenced by the Layer file.



After loading the data in a new ArcMap document, arrange the data layers as shown here.

3. Examine these files using both Geography and Tables view and look at the metadata. Note that this data is in the Washington State Plane North Zone coordinate system using the North American Datum for 1983 (NAD 83) and U.S. Survey Feet as units of measure.

4. Carefully preview the streets_nw data table. It includes fields for length in both feet and miles and a field recording travel time in minutes. These fields contain zero values but will be populated later using the Field Calculator. Notice that the OneWay and MPH fields contain important Network Analyst travel restriction and impedance values.

5. Start ArcMap and create a new map document. Load all the Layer files except the 10 Minute Optimum Polygons. All data layers share the same coordinate system (i.e., Washington State Plane North Zone), and each file contains proper projection metadata so the incoming layer files set the coordinate system for the Data Frame. Arrange layers in the following order (from top to bottom):

   Fire Hydrants

   Fire Stations

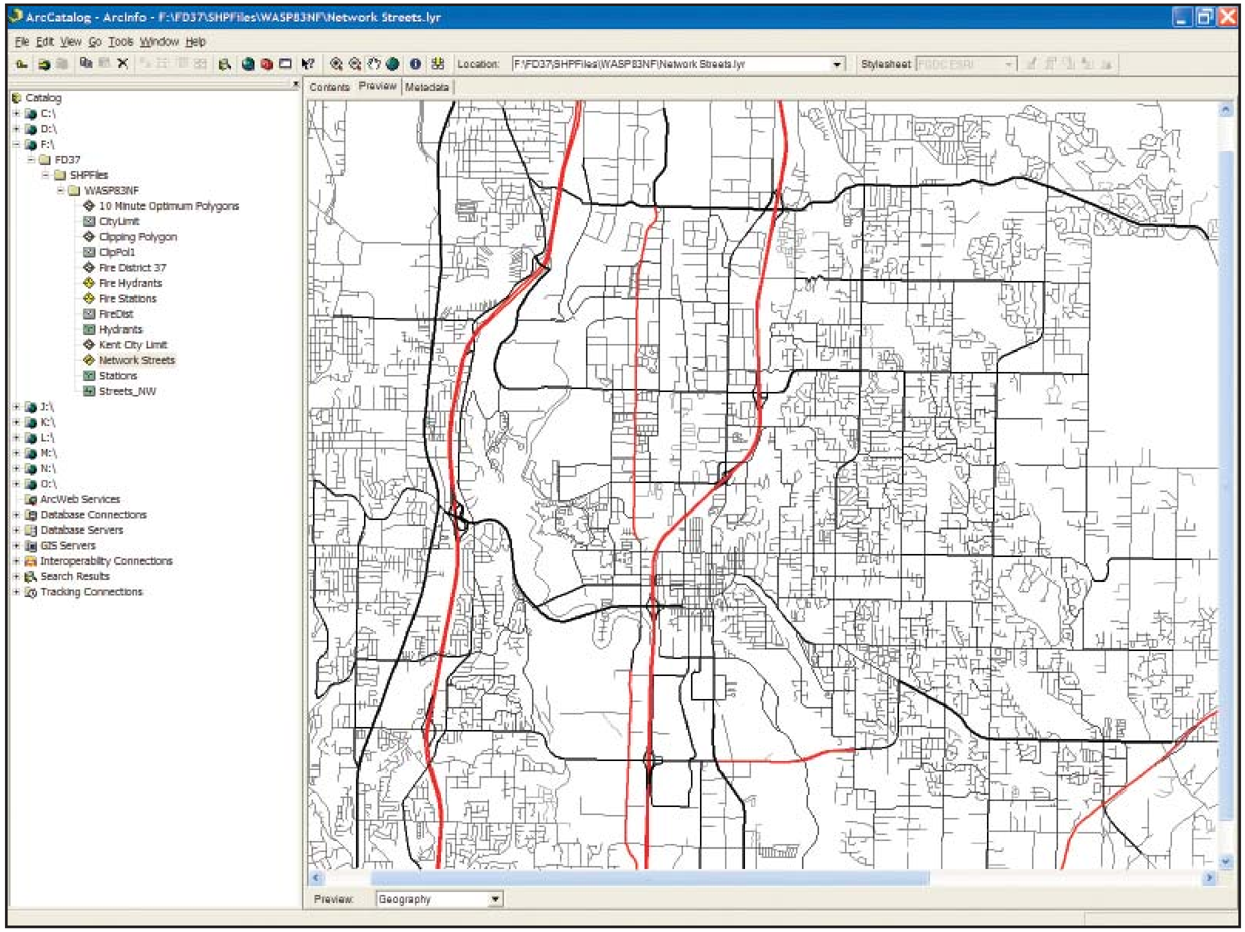
   Network Streets

   Kent City Limit

   King County Fire District 37

   Clipping Polygon

6. Save the map as FD37_1.mxd. Open the Network Streets table to calculate lengths and impedance values for three important fields.



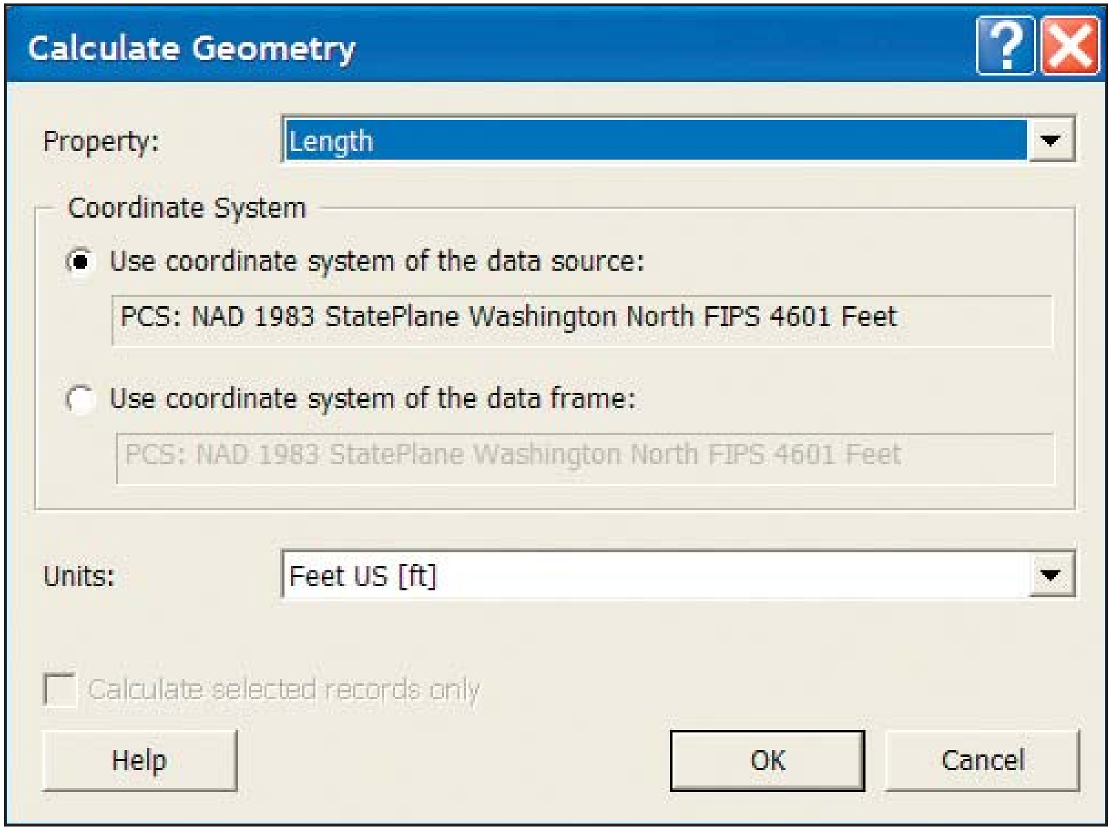
Preview the sample data in ArcCatalog.

New ArcGIS 9.2 Tools for Calculating Fields

ArcGIS 9.2 contains an important new toolset to calculate data geometry directly within a table.

1. Open the Network Streets attribute table and verify that no records are selected. Locate the Length_Ft field and right-click on the field name. Notice a new choice on the context menu called Calculate Geometry. Click on it.

2. In the Calculate Geometry dialog box, choose Length and Feet US. It will use the coordinate system of the Data Frame. Click OK.



Calculate the polyline properties using the Calculate Geometry dialog box.

3. Use Field Calculator to convert segment lengths from U.S. feet to miles. Right-click on the Length_Mi field and choose Field Calculator. In the Field Calculator, use the expression [LENGTH_FT]/5280 to divide the length in feet by the length of a mile. Inspect the values generated by sorting them in ascending order. Notice that the precision setting precludes a record with a length of zero miles.Finally, calculate the travel time for each segment in minutes. Through field testing, King County Fire District 37 has determined that it is appropriate to assign a travel time for all segments at 80 percent of posted speed limit for streets in the district. To

calculate this value for all segments, right-click on the Minutes field, select the Field Calculator, and type the following equation in the formula box: [LENGTH_MI] *(60/([MPH]*0.80)).

4. Click OK to perform the calculation for all 14,115 records. Manually calculate the value for a few records to check the output. Save the map again and close ArcMap.

Creating a Network Dataset

The network dataset is built in ArcCatalog. This exercise uses a simplified version of the city of Kent street network that has been tuned to run quickly and consistently for this project. Two impedances—one for distance and one for time—will be created, and one-way travel on the freeways will be respected.

1. Reopen ArcCatalog and choose Tools > Extensions, and verify that the Network Analyst extension is available.

2. Navigate to the streets_nw shapefile. Right-click on it and select New Network Dataset. Accept the default name streets_nw_ND and click Next to continue. Click the Connectivity button to verify that simple End Point rules will be used in creating this network dataset. Click OK and click Next.

3. The street network already includes freeway crossings so there is no need to modify the elevation connectivity field. Click the radio button next to No. Click Next again.

4. Click the radio button next to Yes to model Global turns. Click Next.

5. Notice that Minutes and Oneway are both reserved Network Analyst field names. Because these names match appropriate fields on the network dataset, Network Analyst identifies these fields and sets them up for the network. Specify one additional impedance attribute field. Manually add Length_Mi, the distance field, by clicking Add and typing Length_Mi in the Name box. Leave Usage Type as Cost, change Units to Miles, and leave Data Type as Double. Click OK. Click Next again.

6. Leave the driving directions as Yes, the default choice. Click Next.

7. The next pane lists network dataset parameters. Check that they match the parameters listed in Table 1. Before clicking Finish, select the listed parameters, copy them to the system clipboard, and paste them into a WordPad document. Save this file with the network data for future reference.

New Network Dataset	Parameters	Action
Name	streets_nw_ND	Click Next
Connectivity	streets_nw End Point	Click OK, Click Next
Elevation Data Field	No	Click Next
Model Turns	Yes, Global Turns Checked	Click Next
Network Attributes	(Default) Minutes, Cost, Minutes, Double	Click Next
	(Default) Oneway, Restriction, Unknown, Boolean	
	(Add) Length_Mi, Cost, Miles, Double	
Driving Directions	Yes	Next
List of dataset parameters	(Lists parameters set)	Check, Copy to Wordpad, Click Finish

Table 1: Set new network dataset parameters in ArcCatalog

8. Click Finish to create the new network dataset. Click Yes to build the dataset. The new network dataset consists of a street feature class named streets_nw_ND and a point feature class named Streets_nw_ND_Junctions. Inspect these files and close ArcCatalog.

Building a 1.5-Mile Service Area

Reopen ArcMap and reopen FD37_1.mxd to begin creating four Service Areas. One Service Area will be based on distance and the other three on time. Each Service Area will provide more information about the level of service (i.e., the standard of cover or SOC) provided by Fire District 37.

Facilities Parameters	
Load From:	Fire Stations
Sort Field:	None
Location Analysis Properties	
Curb Approach	Either side of vehicle
Attr_Minutes	0
Name	LABEL
Attr_Length_Mi	0
Breaks_Minutes	Blank
Breaks_Length_Mi	Blank
Location Position	
Use Geometry	500 Feet

Table 2: Loading parameters for fire station facilities

King County Fire District 37 presently staffs seven fire stations located in and near the city of Kent, Washington. As growth extends to the southeast and the west, Fire District 37 wishes to provide a higher level of service in rural areas. Sites have been identified for two additional stations east of the incorporated city and one new station in the western area of the core community. With Network Analyst, travel footprints can be created for both existing and proposed stations and modeled to show best alternatives for deployment of equipment and personnel.

Study the fire stations carefully. The existing stations are numbered 71 through 77 and the proposed stations, 78, 79, and the Washington Avenue station, a large station with a full firefighting force and chief, engine, and ladder. The attributes table for the Fire Stations layer lists the apparatus (i.e., firefighting equipment) and personnel planned for these proposed sites.

1. Using the Tools > Extensions selection on the text menu, verify that the Network Analyst extension is available, and open the Network Analyst toolbar. Explore the drop-down menu and hover the mouse cursor over the tool buttons to read the Tool Tips.

2. Add Streets_nw_ND to the map and make sure it is the active network dataset. In the Network Analyst toolbar, click the Show/Hide Network Analyst window button to make this window visible.

3. Click the Network Analyst drop-down menu and select New Service Area. The Network Analyst window (located to the right of the table of contents) now references the new Service Area and lists four possible network data types: Facilities, Barriers, Polygons, and Lines.

4. Right-click on Facilities and select Load Locations. Select Fire Stations as the Facilities layer and fill out all fields as listed in Table 2. Be especially careful to select the LABEL field as the Name property. A 500-foot search tolerance limits station locations to within one block of existing streets. This should be sufficient for locating new and current stations. Click OK to accept these parameters and load the fire stations. Verify that 10 stations are shown (including the proposed station on North Washington Avenue).

5. Right-click Service Area in the table of contents, choose Properties, click the General tab, and change the name to 1.5 Mile ISO Service Area. Click on the other seven tabs in this dialog box and change the setting for each as shown in Table 3a. After completing all tabs, save the map document, click OK, and create the first Service Area by clicking the Solve button on the Network Analyst toolbar or by right-clicking on the SA name in the TOC and selecting Solve. This operation could require several minutes to complete.

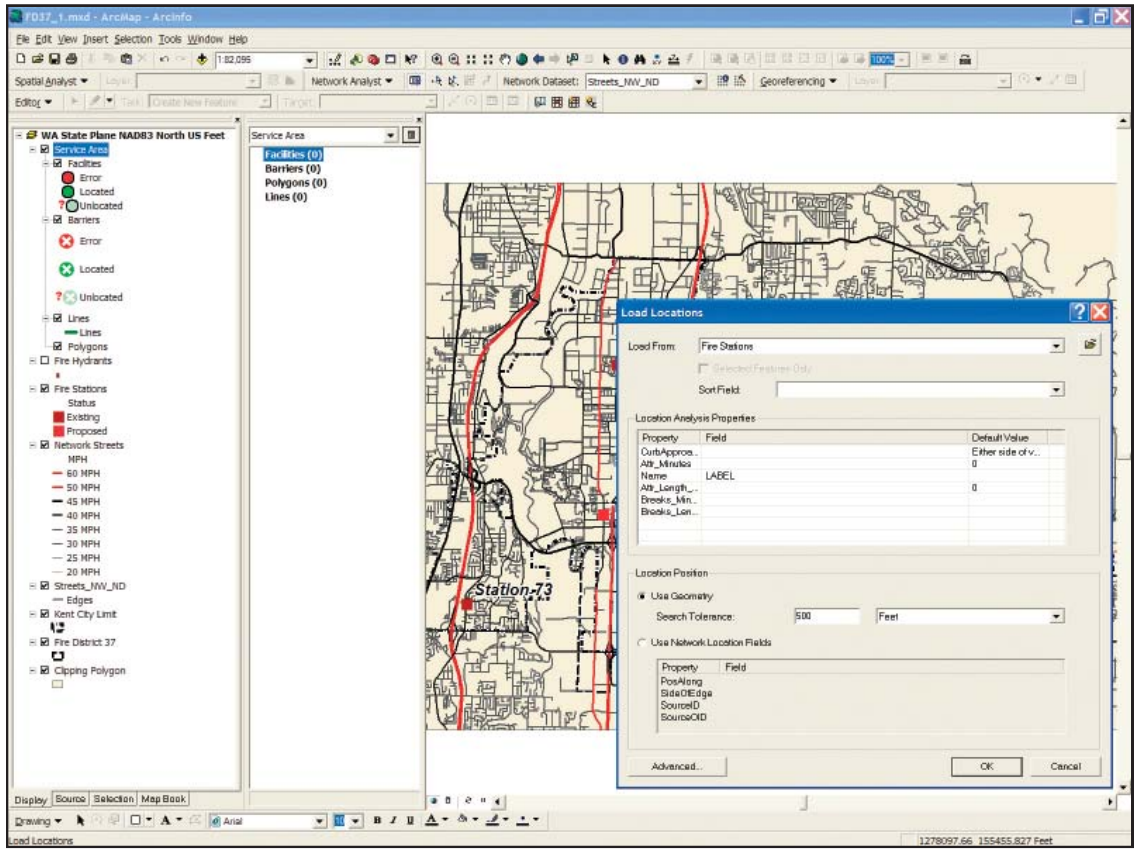
   The first SA models 1.5-mile travel away from all fire stations. By trimming all polygons to

1.5 Mile Service Area Wizard Settings	
Analysis Settings Tab	
Impedence	Length_Mi
Default Breaks	1.5
Direction	Away From Facility
Allow U-Turns	Everywhere
Ignore Invalid Locations	Checked
Restrictions	Oneway
Polygon Generation Tab	
Generate Polygons	Checked
Polygon Type	Detailed
Trim Polygons	200 Feet
Excluded Sources	None
Multiple Facility Options	Overlapping
Overlap Type	Disks
Line Generation Tab	
Generate Line	Checked
Generate Measure	Unchecked
Split Lines at Breaks	Unchecked
Include Network Source Fields	Unchecked
Overlapping Options	Overlapping
Accumulation Tab	
Length_MI	Checked
Minutes	Checked
Network Locations Tab	
Location Type	Facilities
Properties	Default for all
Search Tolerance	500 Feet
Snap To	Closest
Streets_nw shapefile	Checked

Table 3a: Parameters for 1.5 Mile ISO Service Area

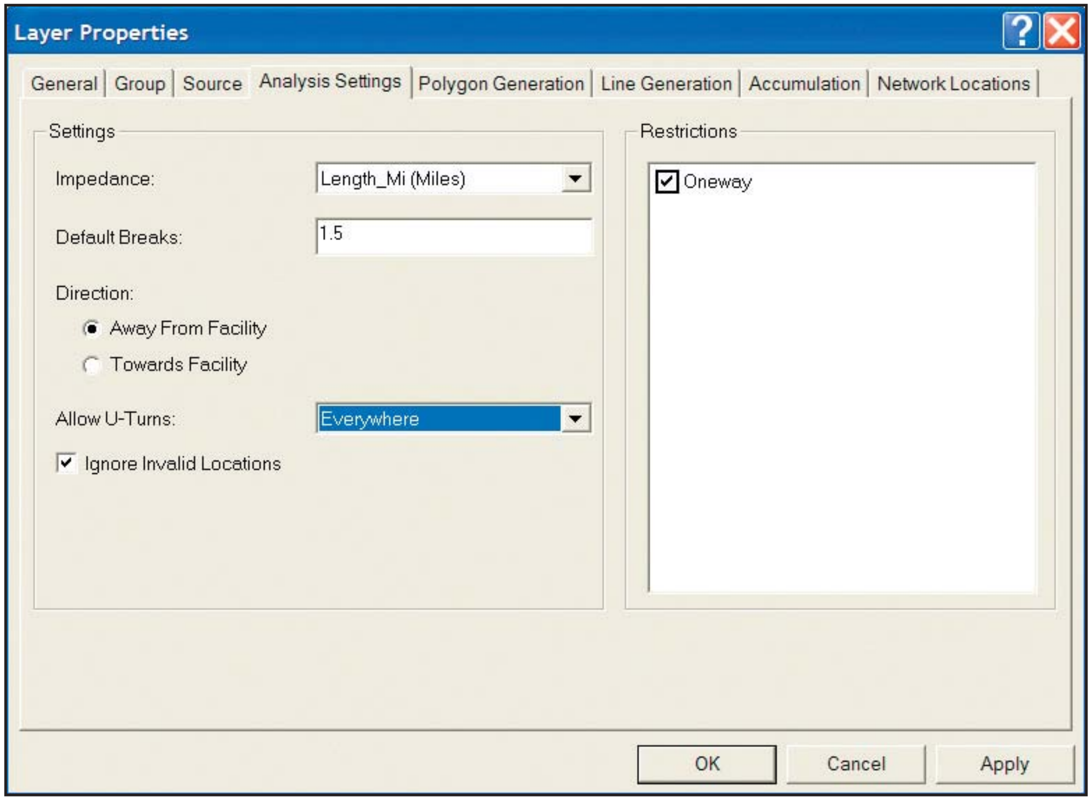
within 200 feet of an existing road, the travel footprint will be limited to an area defined by length of the preconnected fire hoses carried by most structural engines.

6. In the Network Analyst window, right-click on Polygons to open the Properties dialog box. Notice that the SA polygons have been labeled with the 1.5-mile analysis parameter (see Symbology tab) and are posted with a 50 percent transparency (see Display tab). Click the General tab and rename this layer 1.5 Mile Polygons. Change the transparency to 0 percent. Save the map document. Right-click on the Lines layer in the 1.5 Mile ISO Service Area and change the line width from 3.00 to 1.00.



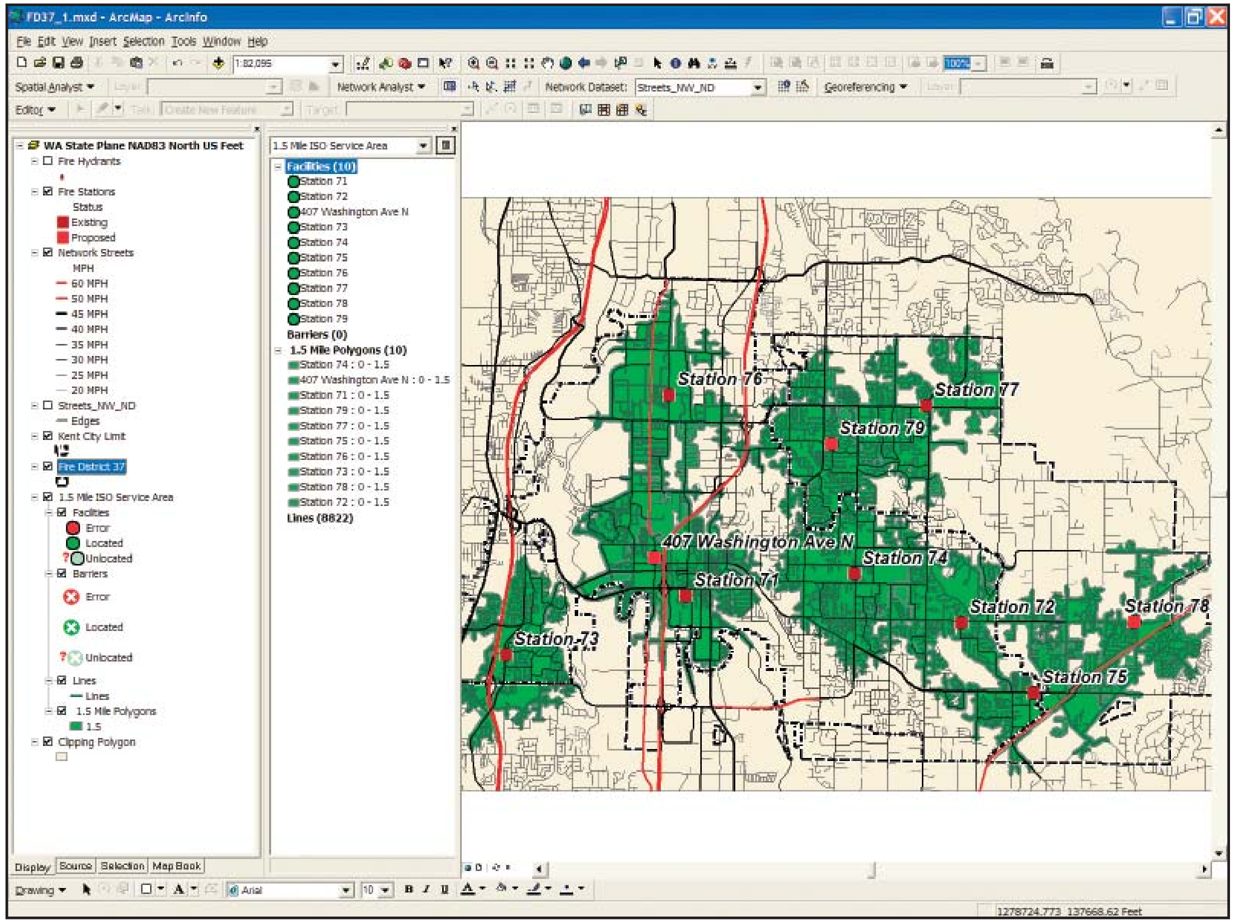
In the Network Analyst window, right-click on Facilities, choose Load Locations from the context menu, and add Fire Stations as locations.

7. Move the 1.5 Mile ISO Service Area layer group down in the table of contents below the King County Fire District 37 layer. Before moving the group, uncheck its group display box, turn off the Fire Hydrants layer, and hide the legend detail to make it move more easily and display more quickly.



Right-click on the newly created service area and set the properties on the tabs as shown in Table 3a.

8. Before building the rest of the Service Areas, perform a basic spatial calculation that counts the number of hydrants inside and outside the 1.5-mile polygons. Highlight the Fire Hydrant layer and make all 3,495 hydrants visible. From the main menu, choose Selection > Select by Location and select features from Fire Hydrants that are completely within the features in 1.5 Mile Polygons. This should select 2,201 hydrants inside the 1.5-mile Service Areas. Choose Selection > Clear Selected Features to unselect these features and save the map document.



The first service is based on distance.

Creating a Five-Minute Travel Area

To develop and implement a Standard of Cover, emergency service providers map predetermined time-based travel areas around fixed facilities. King County Fire District 37 maps five- and eight-minute travel around all existing stations and also maps similar areas around proposed stations to define new coverage. Staff determined that time-based travel is measured by averaging travel on each street segment applying 80 percent of the posted speed limit. Streets in the sample dataset do not include turn restrictions or traffic calming features, although these features are being mapped by the city.

1. To define five-minute travel areas, click the Network Analyst drop-down list and select New Service Area and make sure streets_nw_ND is the active Network Dataset.

2. Right-click on locations and choose Fire Stations. Right-click on the new SA layer group and choose Properties. Rename it 5 Minute Travel Area and go through each tab changing parameters as shown in Table 3b. Be sure to set impedance to five minutes and change the trimming distance to 600 feet.

3. Move the SA group down the table of contents to a position just below the 1.5 Mile ISO data.

4. Highlight the 5 Minute Travel Area layer and click the Solve button. Inspect the results and tidy up the thematic legend.

5. Rename the polygons to 5 Minute Travel Polygons and save the map document.

This polygon and polyline group shows the first due response area for fire service personnel. Nearly all of the city of Kent and much of the area east of town is covered. Inspect the polygons carefully and notice that there is limited overlap. The Standard of Cover for Fire District 37 specifies that a first arriving unit (or Distribution) will be on scene within seven minutes after an aid request is received for at least 80 percent of all calls. Study the

5 Minute Travel Area Wizard Settings	
Analysis Settings Tab	
Impedence	Minutes
Default Breaks	5
Direction	Away From Facility
Allow U-Turns	Everywhere
Ignore Invalid Locations	Checked
Restrictions	Oneway
Polygon Generation	
Generate Polygons	Checked
Polygon Type	Detailed
Trim Polygons	600 Feet
Excluded Sources	None
Multiple Facility Options	Overlapping
Overlap Type	Disks
Line Generation	
Generate Line	Checked
Generate Measure	Unchecked
Split Lines at Breaks	Unchecked
Include Network Source Fields	Unchecked
Overlapping Options	Overlapping
Accumulation	
Length_MI	Checked
Minutes	Checked
Network Locations	
Location Type	Facilities
Properties	Default for all
Search Tolerance	500 Feet
Snap To	Closest
Streets_nw shapefile	**Checked**

Table 3b: Parameters for 5 Minute Travel Area

Fire Stations attribute table to understand the apparatus and staffing available for first due response.

Measuring Eight-Minute Travel

The next step is modeling eight-minute travel to analyze combined response capabilities, relying on equipment and personnel from multiple stations. This portion of the exercise models combined response. This allows units three extra minutes to arrive and deploy and lay attack lines 600 feet from apparatus.

1. Close the 5 Minute Travel Area group and create a new SA as described in the two previous sections.

2. Name this group 8 Minute Travel Area and set analysis parameters as shown in Table 3c. Be sure to set the trimming distance on the Polygon Generation tab to 600 feet.

3. Reposition the 8 Minute SA just below the 5 Minute analysis and click the Solve button. This solution will require slightly more time because it will cover more distance and entail significantly more overlapping coverage. When this routine finishes, tidy up the legends, rename the polygons to 8 Minute Travel Polygons, and inspect the results.

4. Observe the extensive overlap between stations. These relationships, called Concentration in Standard of Cover terms, can also be modeled. King County Fire

8 Minute Travel Area Wizard Settings	
Analysis Settings Tab	
Impedence	Minutes
Default Breaks	8
Direction	Away From Facility
Allow U-Turns	Everywhere
Ignore Invalid Locations	Checked
Restrictions	Oneway
Polygon Generation	
Generate Polygons	Checked
Polygon Type	Detailed
Trim Polygons	600 Feet
Excluded Sources	None
Multiple Facility Options	Overlapping
Overlap Type	Disks
Line Generation	
Generate Line	Checked
Generate Measure	Unchecked
Split Lines at Breaks	Unchecked
Include Network Source Fields	Unchecked
Overlapping Options	Overlapping
Accumulation	
Length_MI	Checked
Minutes	Checked
Network Locations	
Location Type	Facilities
Properties	Default for all
Search Tolerance	500 Feet
Snap To	Closest
Streets_nw shapefile	Checked

Table 3c: Parameters for 8 Minute Travel Area

District 37 exhibits excellent Distribution and Concentration as defined by its Standard of Cover, especially after the construction of several new stations. The total available response for firefighting force can be determined by summing all available personnel responding within overlapping eight-minute travel areas.

Mapping Optimum Response Areas

The final process in this exercise will model optimum response areas based on a 10-minute travel limit from each station. In this analysis, apparatus from each station will drive outward on all streets until each meets apparatus from a neighboring station. Time-based travel polygons show optimum response areas for all stations. In many fire departments, each station is responsible for testing and maintaining fire hydrants within its response area. Counting the hydrants within each station's optimum area will help determine if some stations have significantly more hydrants to inspect.

1. From the Network Analyst drop-down list, create another Service Area and name it 10 Minute Optimum Response Area.

2. Modify the parameters in the Layer Properties dialog box as shown in Table 3d. Pay special attention to the Polygon Generation tab. On that tab, keep the trim distance at 600 feet, and under Multiple Facilities Options, select Not Overlapping.

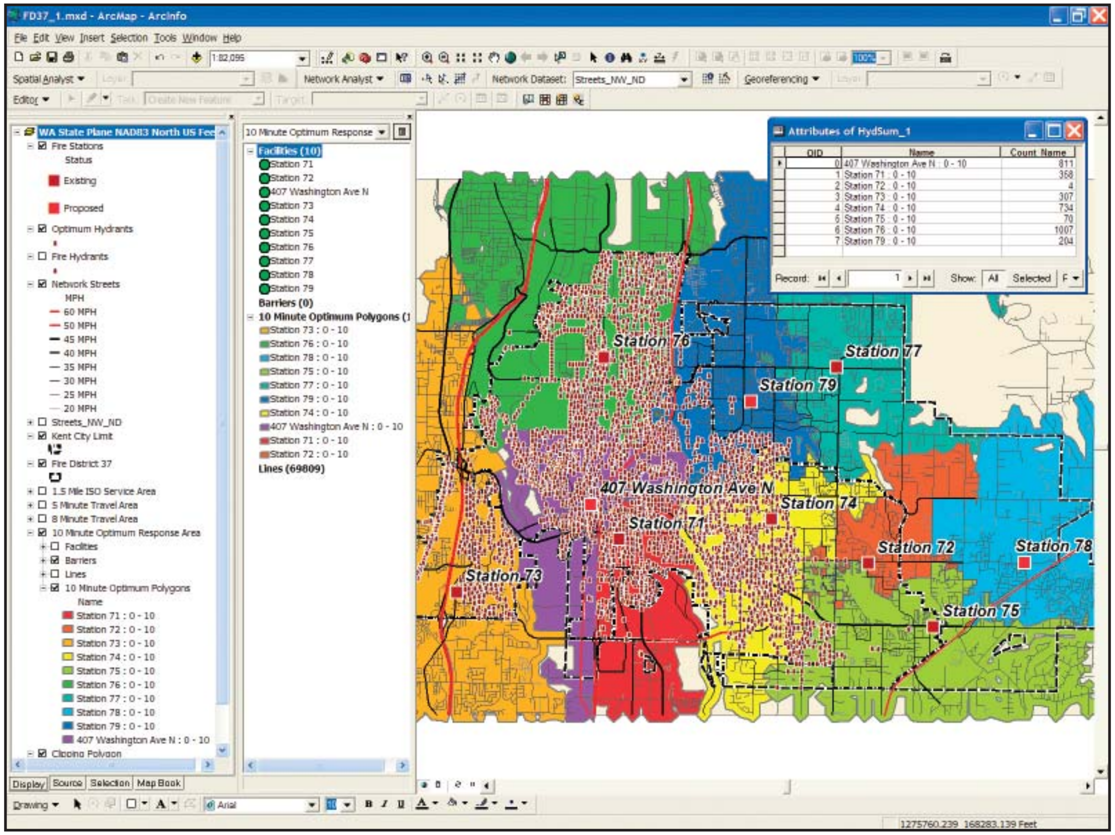
10 Minute Optimum Response Area Wizard Settings	
Analysis Settings Tab	
Impedence	Minutes
Default Breaks	10
Direction	Away From Facility
Allow U-Turns	Everywhere
Ignore Invalid Locations	Checked
Restrictions	Oneway
Polygon Generation	
Generate Polygons	Checked
Polygon Type	Detailed
Trim Polygons	600 Feet
Excluded Sources	None
Multiple Facility Options	Overlapping
Overlap Type	Disks
Line Generation	
Generate Line	Checked
Generate Measure	Unchecked
Split Lines at Breaks	Unchecked
Include Network Source Fields	Unchecked
Overlapping Options	NOT Overlapping
Accumulation	
Length_MI	Checked
Minutes	Checked
Network Locations	
Location Type	Facilities
Properties	Default for all
Search Tolerance	500 Feet
Snap To	Closest
Streets_nw shapefile	Checked

Table 3d: Parameters for 10 Minute Optimum Response Area

3. Move this layer below the 8 Minute Travel Area group and click the Solve button.

4. When processing is finished, right-click on Polygon to open the Layer Properties dialog box and rename it 10 Minute Optimum Polygons.

5. Close the Network Analyst window. Load the prebuilt Layer file from the sample dataset to create a thematic legend for this data. Save map.



After creating the 10 Minute Optimum Response Area, apply its prebuilt legend, 10 Minute Optimum Polygons, to the polygons.

Future Activities

This tutorial has performed several of the analyses that a public safety provider might perform to measure its effectiveness. Additional tasks might include measuring effective response force, experimenting with Concentration variables including repositioned apparatus and personnel, and comparing historic response times to modeled values. To perform these analyses on your own data, start building and testing network datasets, mapping fire stations and hydrants, and compiling historic response data.

Developing a Standard of Cover

Quick response to fires and medical emergencies limits suffering. Emergency service providers strive to provide similar levels of service in all areas of a city. Equity, timely service, and integrated response are the goals when planning emergency service distribution.

A Standard of Cover (SOC) is a plan that includes mapping and modeling of distribution (e.g., first due responders) and concentration (e.g., multiple responders) of field resources. An SOC also addresses the values, hazards, and associated risks within the community. A successful SOC must show how lives will be saved and property protected, while responders are operating in a safe and timely manner. The Commission on Fire Accreditation International (CFAI), a member of the Center for Public Safety Excellence, guides and certifies emergency service providers and designs, implements, and supports an effective SOC.

The City of Kent Fire Department and King County Fire District 37 in south King County, Washington, began considering the CFAI accreditation process in fall 1997 after a self-assessment workshop was held. Most of the workshop attendees were Kent Fire Department personnel along with personnel from surrounding agencies. Accreditation tasks began in 2001, and following the first peer review, the agency was accredited in August 2004. The district was only the fourth accredited agency in the state.

The accreditation documentation for the City of Kent Fire Department and King County Fire District 37 totaled more than 800 pages of self-assessment information and a dynamic 200-page SOC document. GIS mapping was used extensively to support both documents. The district is currently updating all maps and performance history. It recently completed its annual compliance report and continues building on the original recommendations. The new Information and Strategic Services Unit now implements the recommendations made by peer assessors. GIS enables agency staff as they track recent performance and plan future resource deployment throughout a rapidly growing and changing community.

Acknowledgments

The author thanks the administration and staff of King County Fire District 37, South King County, Washington, and the many Fire District 37 and City of Kent staff who provided data for this exercise as well as the Commission on Fire Accreditation International and ESRI's Public Safety Marketing Group for its continued support of new developments in Standard of Cover GIS mapping.

(Reprinted from the October–December 2006 issue of *ArcUser* magazine)

Managing Volunteer Firefighter Response

Using the OD Cost Matrix to Model Personnel Availability

By Mike Price, Entrada/San Juan, Inc.

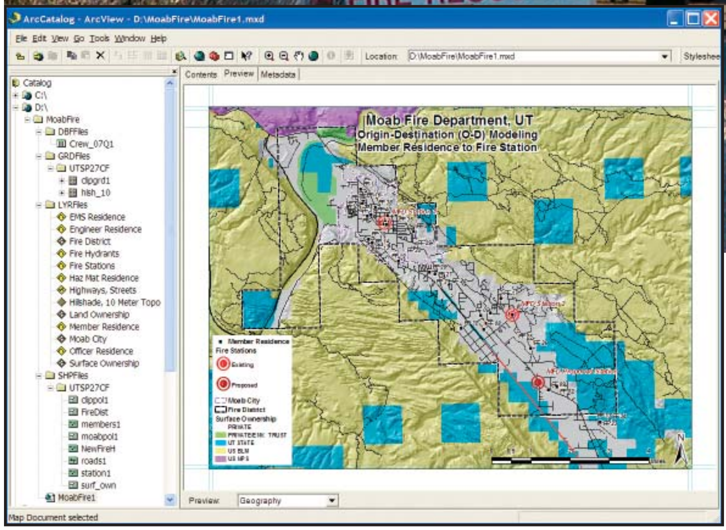
Emergency responders try to arrive on the scene of a fire or other emergency as quickly and safely as possible. Career firefighters respond on a 24/7 basis from fire stations or apparatus in the field. Volunteer responders, who include firefighters and emergency medical technicians, typically respond from homes, workplaces, or random locations.

Depending on department policy and response parameters, volunteers may respond to incidents in privately owned vehicles (POVs) or drive in a POV to a nearby fire station and respond in emergency apparatus. The additional time required for a volunteer responder to travel to a station to pick up emergency apparatus must be factored into a response model. Volunteers are not always available on a consistent schedule, and this must be considered when mapping an effective firefighting force.

The ArcGIS Network Analyst extension has an Origin-Destination (OD) cost matrix function that allows public safety GIS personnel to accurately determine and map travel times and distances from volunteer locations to a fire station. The OD cost matrix also determines optimal apparatus travel time to historic incidents and to hypothetical or staged scenarios, thereby validating historic data and supporting the design of response alternatives.

The Moab Valley Fire Protection District (MVFPD) protects lives and property from fire, flood, man-made, and natural disasters in an approximately 30-square-mile district. The district encompasses the entire resort destination city of Moab, Utah, and adjacent lands in Grand County outside the city limits. According to 2000 census figures, the district's permanent population is 7,723 people and another 209 people live in the district's contract response areas. The Fire Department roster averages 40 volunteer firefighters, based in two fire stations. The department maintains three full-time employees and operates a fleet of 16 vehicles, and the district maintains three full-time employees.

The exercise presented here uses modified firefighter residence locations and actual fire station sites in Moab to map and model volunteer response parameters. Although personnel data has been masked to ensure privacy, its composition and geographic distribution are realistic.



This article models volunteer response using data from Moab, Utah.

Network Analyst and the OD Cost Matrix

Functionality in the ArcGIS Network Analyst extension for calculating travel times and/or distances between families of origin and destination points was available at ArcGIS 9.1 and updated in ArcGIS 9.2. This group function, the OD cost matrix, quickly provides emergency service providers with measures of staff availability and response effectiveness. The procedure employs the same high-quality network dataset that emergency managers use for determining service areas, optimal routing, and other tasks. The OD cost matrix requires careful mapping of origin and destination point locations. The matrix records time and distance data for each pair of points and maps a two-node polyline connecting the endpoints.

Two primary uses for the OD cost matrix in public safety involve managing personnel and fire response preplanning. Emergency managers continually track availability of resources including volunteer responders. The OD cost matrix calculates travel times and distances for volunteer personnel traveling in personal vehicles from homes and offices to a station.

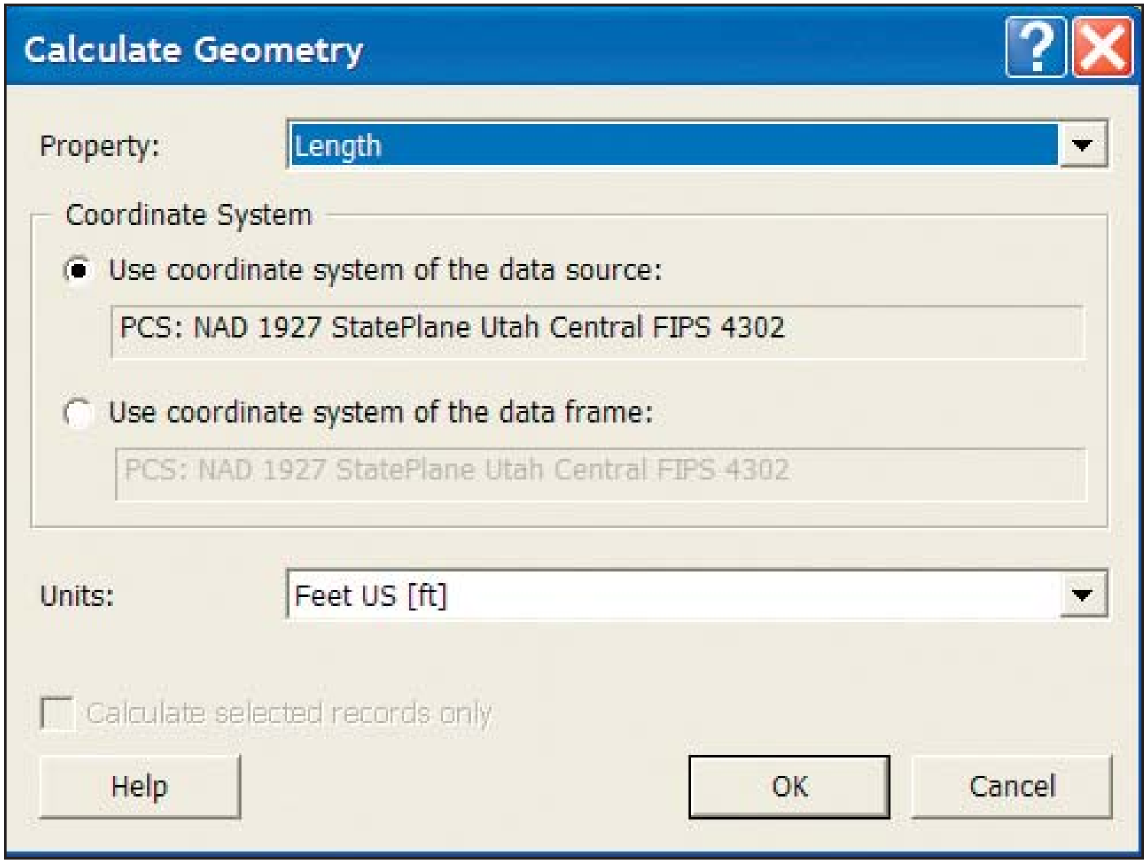
The OD cost matrix also calculates optimal travel times along shortest routes for historic incident responses; it provides a framework to confirm whether incident time tracking is accurate and determines where performance might be improved. This exercise shows how the OD cost matrix maps and assesses volunteer firefighter availability in a rural community that has 40 firefighters who will respond to any of three fire stations from their homes.

To add a bit of sophistication, this exercise will also use joined tabular data for determining travel parameters for a rotating Officer in Charge and available responders from a weekend roster. In practice, this model should be expanded to include work addresses and other predictable time-based locations for responders.

Getting Started

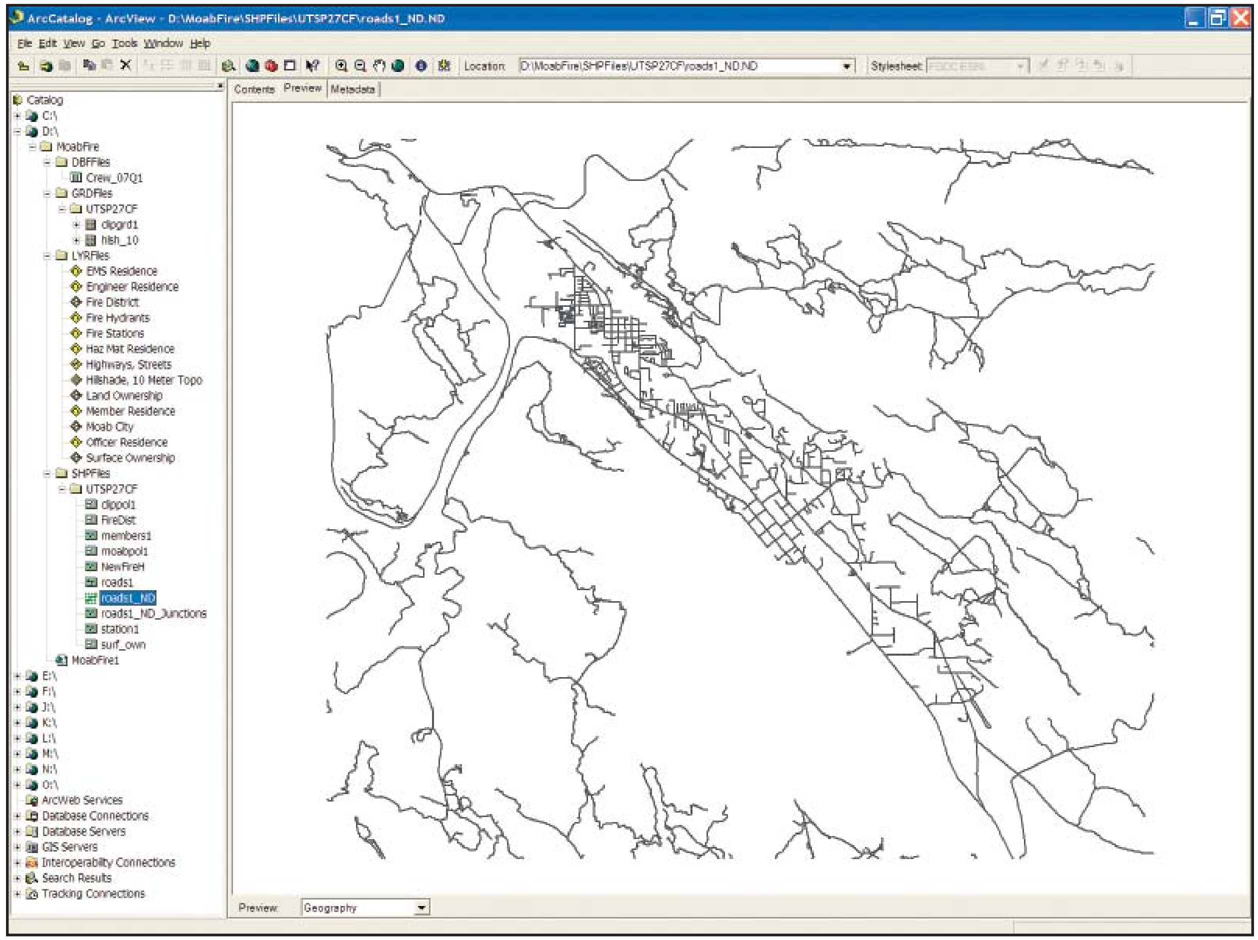
1. Download the sample data for this exercise from *ArcUser Online* at www.esri.com/arcuser. Unzip the archive file in the root directory. Open ArcCatalog and inspect the files. The sample dataset contains one dBASE file, a topography hillshade grid, many Layer files, several shapefiles, and a startup ArcMap document. All data is registered in Utah State Plane Central Zone. The datum is North American Datum 1927, and units of measure are U.S. Feet.

2. Using ArcCatalog, inspect the data attributes to verify they will support time-based networking. Navigate to \MoabFire\LYRFiles\ and locate the Highways, Streets :Layer file and preview its attribute table.



In the Highways, Streets attribute table, use Calculate Geometry to calculate the contents of the LENGTH_FT field.

3. Scroll right and notice that this table contains fields for geocoding addresses. These streets are a subset of streets mapped by Grand County's Road Department as part of a U.S. Geological Survey rural transportation prototype program. This data is used by Grand County Emergency Management for geocoding incidents. The Speed_MPH column will be used to calculate travel time along segments. The three rightmost columns—Length_FT, Length_MI, and MINUTES—contain zeroes and will be used to record impedance data: segment length in U.S. feet and miles and travel time in minutes.



Inspect the roads1_ND in ArcCatalog.

4. Preview the table for the Fire Stations layer. The Moab Valley has two existing stations and one proposed station, now occupied by a temporary apparatus facility. The Index and Label fields are very helpful for loading locations for network analysis.

5. Inspect the Members Residence table. It contains the same Index and Label fields. This exercise includes data for 40 firefighters including a chief, an assistant chief, two battalion chiefs, four captains, four lieutenants, and 28 firefighters. Fields on the right track training status including engineering, emergency medical, and hazardous material certifications. These fields will help verify that sufficient officers, engineers, and other specially trained personnel will be available during an emergency.

6. Finally, navigate to \MoabFire\DBFFiles\ and preview Crew_07Q1.dbf. This table lists scheduled availability of firefighters on weekends during the first three months of 2007. The number 1 indicates that a firefighter will be available through the weekend, and a 2 identifies the Officer in Charge for that weekend.

7. Click on several headers for these columns and choose Statistics from the context menu. More than 24 firefighters are available for weekend response on all but two holiday weekends, when availability drops to less than 20. (Hint: Subtract 1 from the sum to account for the Officer in Charge. The sum generated by Statistics represents 23 firefighters and one officer.)

Calculating Distances and Travel Times

Before using ArcCatalog to create the Roads_1 Network Dataset, distances and travel times must be calculated in ArcMap.

1. Start an ArcMap session and open \MoabFire\MoabFire1.mxd.

2. Open the Highways, Streets attribute table and move to the LENGTH_FT field. Right-click on this field and select Calculate Geometry, a new ArcGIS 9.2 function.

3. Set Property as Length, click on the radio button next to Use Coordinate System of the Data Source. Make sure the units are Feet US [ft] and click OK.

4. Right-click on the LENGTH_MI field header and select Field Calculator. Enter [LENGTH_FT]/5280 in the formula box, click OK, and check these calculations.

5. Calculate the travel time in minutes for each segment by opening a Field Calculator for the MINUTES column and entering [LENGTH_MI]*(60/[SPEED_MPH]) in the formula box. Click OK, check the final calculations, and return to ArcCatalog.

Creating a Network Dataset

In the ArcCatalog Catalog tree, move to /SHPFiles/UTSP27CF/, open roads1 and preview its table, particularly the rightmost fields.

1. Right-click on roads1 and select New Network Dataset. Accept default parameters for Connectivity, Connectivity Elevation, and Turns.
2. On the Attributes Setting pane, Minutes is a Network Analyst keyword. This field will be included in the dataset. Specify the distance parameter by clicking the Add button and typing Length_Mi in the Name box. Set the Units to Miles, accept other default parameters, click OK, and click Next.
3. Specify driving instructions and capture the text in the Summary screen into a WordPad document for future reference. Click Finish and build the new Network Dataset.
4. Inspect the new Network Dataset. For more information about creating network datasets, read "Got It Covered—Modeling Standard of Cover with ArcGIS Network Analyst 9.2" in the October−December 2006 issue of *ArcUser,* available online at www.esri.com/news/arcuser/1006/files/covered.pdf.

The author thanks the Moab Valley Fire Protection District and Grand County Emergency Management for providing representative data for this activity. All personnel data has been synthesized for training purposes and any resemblance to actual conditions is accidental.

People and Places—Mapping Response Resources

Return to the ArcMap document, MoabFire1. Check that a license for an ArcGIS Network Analyst extension is available, display the Network Analyst toolbar, and open the Network Analyst window by clicking the Network Analyst window.

1. Click the Add Data button and locate the /roads1_ND.ND in /SHPFiles/UTSP27CF and add it to the project. Because this project already includes the source roads and won't use intersection nodes, do not add other feature classes. Verify that the Network Dataset has successfully loaded.

2. Click the Network Analyst drop-down menu and select New OD cost matrix. Right-click on Origins in the Network Analyst window and select Load Locations. Select Member Residences as the Origin set, specify INDEX as the Sort Field and LABEL as the Name field, and set Search Tolerance as 500 Feet. Verify that 40 member origins load successfully.

3. Load the Destination Fire Stations using parameters in Table 1. Verify that three stations are properly mapped.

Parameter	Value
Load From	Fire Stations
Only Show Point Layers	Checked
Location Analysis Properties	Curb/Approach (Default) Name (LABEL)
Location Position	Use Geometry
Search Tolerance	500 Feet

Table 1: Values for loading Destination Fire Stations.

4. Now move the OD Matrix group below the Member Residences and Fire Stations layers in the table of contents. Save the map document.

5. Return to the table of contents and right-click on the OD cost matrix group name. Under the General tab, rename it Firefighter Residence OD cost matrix. Accept defaults for the Layers and Source tabs and open the Analysis Settings tab and set them as shown in Table 2. Click the Accumulation Attributes tab and check both Length_Mi and Minutes, inspect Network Locations, and click OK to set all parameters.

Parameter	Value
Impedance	Minutes(Minutes)
Default Cutoff Value	<None>
Destinations to Find	<All>
Allow U-Turns	Everywhere
Output Shape Type	Straight Line

Table 2: Analysis Settings tab.

6. Solve the OD cost matrix by right-clicking on its name and selecting Solve or by clicking the Solve button on the Network Analyst toolbar. Save the map document.

Mapping Responders

1. Open the attribute table for the Lines layer of the Firefighter Residence OD Matrix group. Inspect fields and observe that there are a number of informative fields including the Name of the firefighter and the modeled station, each firefighter's OriginID (i.e., the firefighter residence index), a DestinationID (the fire station index), a DestinationRank, TotalMinutes, and Total_Length_Mi.
2. Tidy up the OD vectors to highlight each station set with a different color. Minimize the table and open Lines Properties. Select the Symbology tab and change to a Unique Values legend. Specify DestinationID as the Value Field and specify 2 point lines for values 1, 2, and 3 (Stations 1, 2, and 3, via indexing). Select a bright red for 1, green for 2, and blue for 3 to show the connection between each firefighter's home and all stations.
3. Return to the Lines table and experiment with this data. Try to find the closest firefighter to each of the three stations. Who lives the farthest in time and distance from Station 1? Which station is closest to each firefighter's home? (Hint: Query for DestinationRank = 1; do you think that this time-based response information might help resolve a few arguments?)

Enhancing Response Data with Tabular Joins

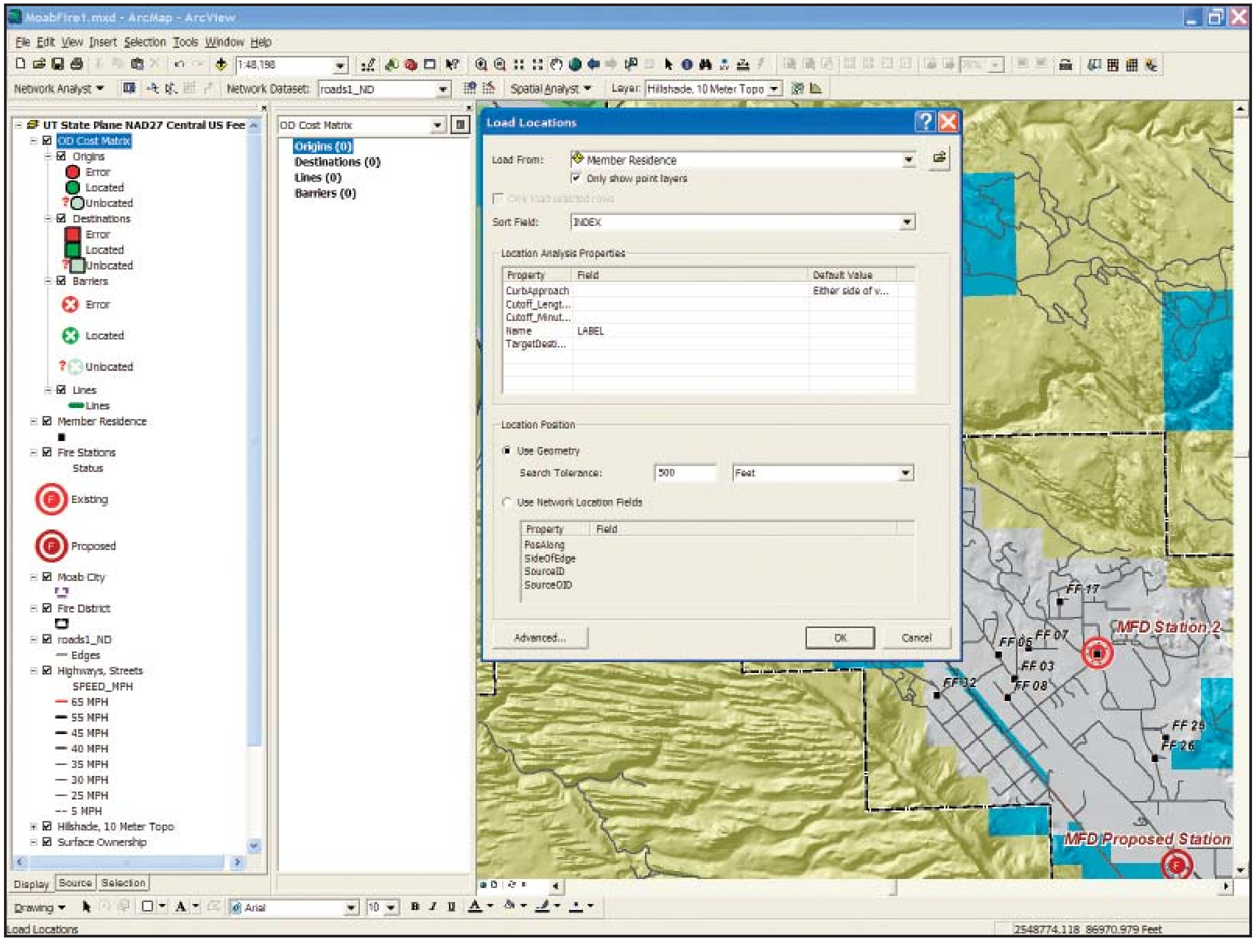
The next step is to model each firefighter's weekend availability.

1. Load a table listing each volunteer's status on weekends by clicking the Add Data button and selecting Crew_07Q1.dbf from \MoabFire\DBFFiles\.
2. Open this table and inspect it. It includes fields for Label, Rank, and the helpful Index. Fields to the right of Rank contain flags listing the weekend Officer in Charge (coded with 2) and available firefighters (coded with 1).
3. In the table of contents, right-click on the Member Residences and choose Joins and Relates > then Join. Select INDEX as the field that the Join will be based on, specify Crew_07Q1 as the table to join, and select INDEX as the key field in the joined table. Click OK and verify the join by opening the attribute table.
4. Repeat this process with the OD Matrix Lines. Select OriginID as the field that the Join will be based on, specify Crew_07Q1 as the table to join, and select INDEX as the key field in the joined table. Click OK and verify the join.

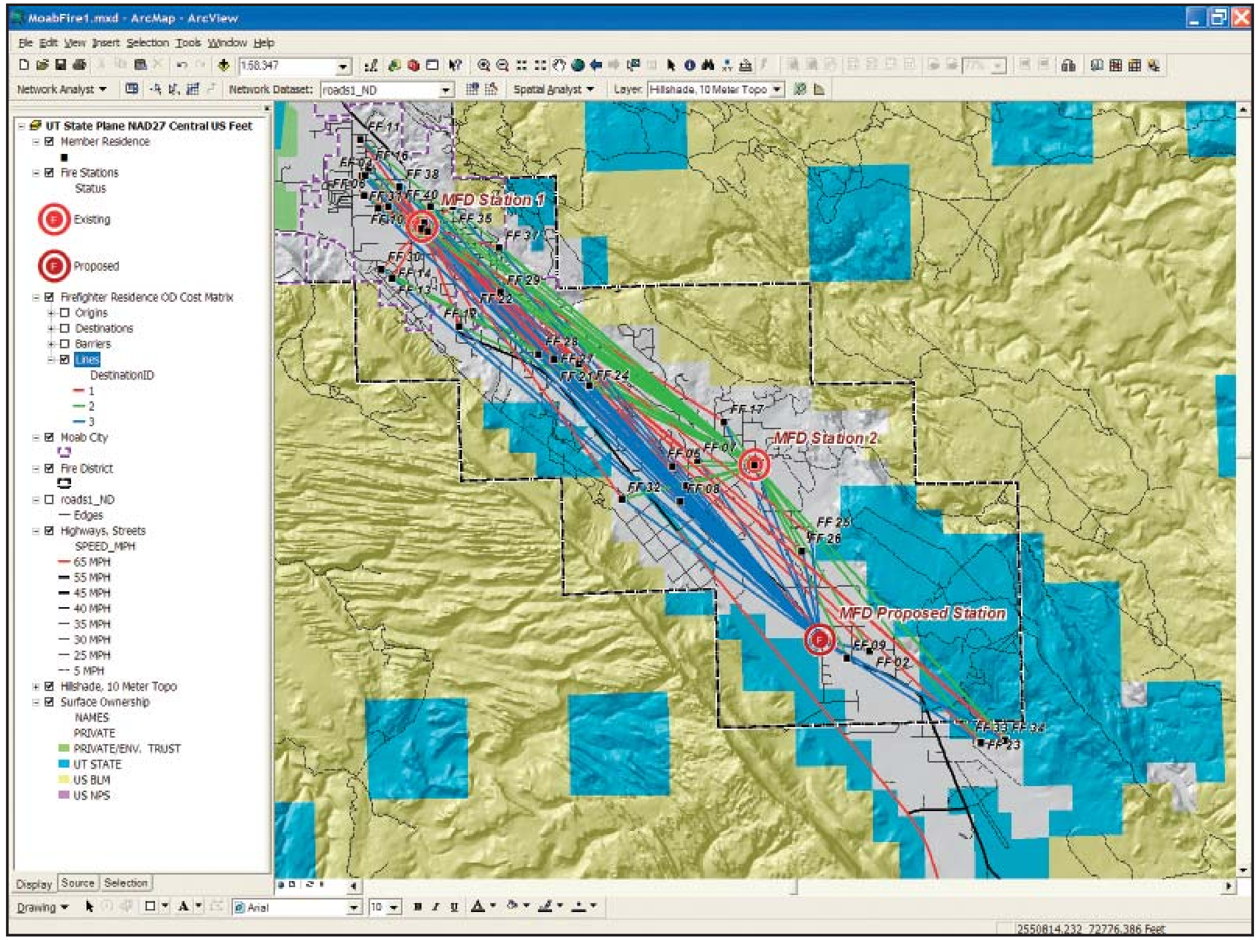
Finding Firefighters—Definition Queries Using Tabular Joins

With the weekend availability data joined to Member Residence points and OD Matrix Lines, definition queries can be applied that will show staff availability. Let's start with the first weekend in January.

1. Double-click on Member Residences, click the Definition Query tab. Click the Query Builder button and use the interface to create the query "Crew_07Q1.A_070106" >0 that will display all firefighters available for the weekend. Click OK.
2. Review the selection. Can you find the Officer in Charge this weekend? What is his/her rank and Engineer/Driver status? How far is the officer's home from Station 1, in terms of time and distance? This query locates the officer's home, rank (e.g., battalion chief), and engineer training but cannot display travel time to Station 1.

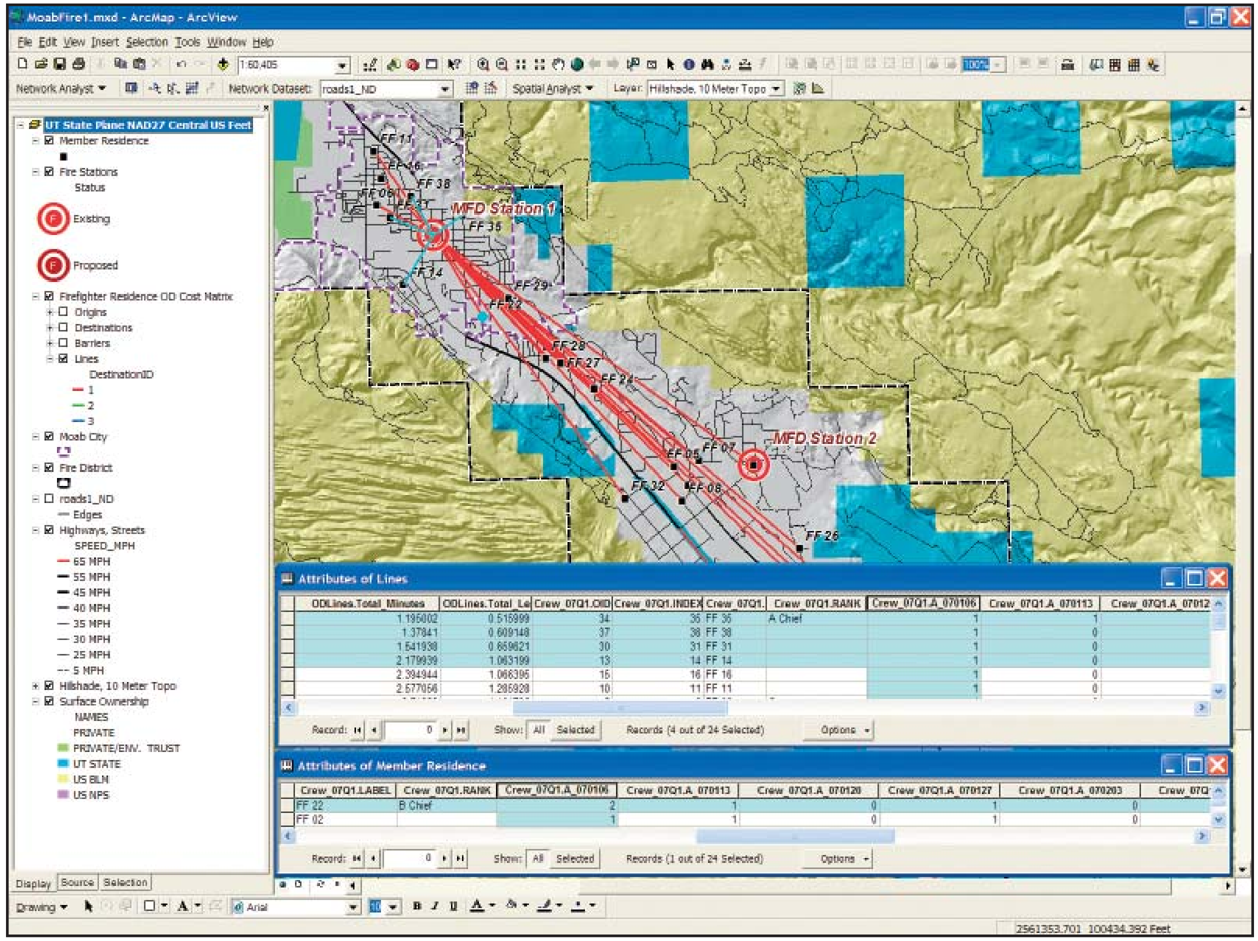


After creating the roads1_ND, click the Network Analyst drop-down menu and select New OD cost matrix, right-click on Origins in the Network Analyst window, and select Load Locations to load the firefighter residence locations.



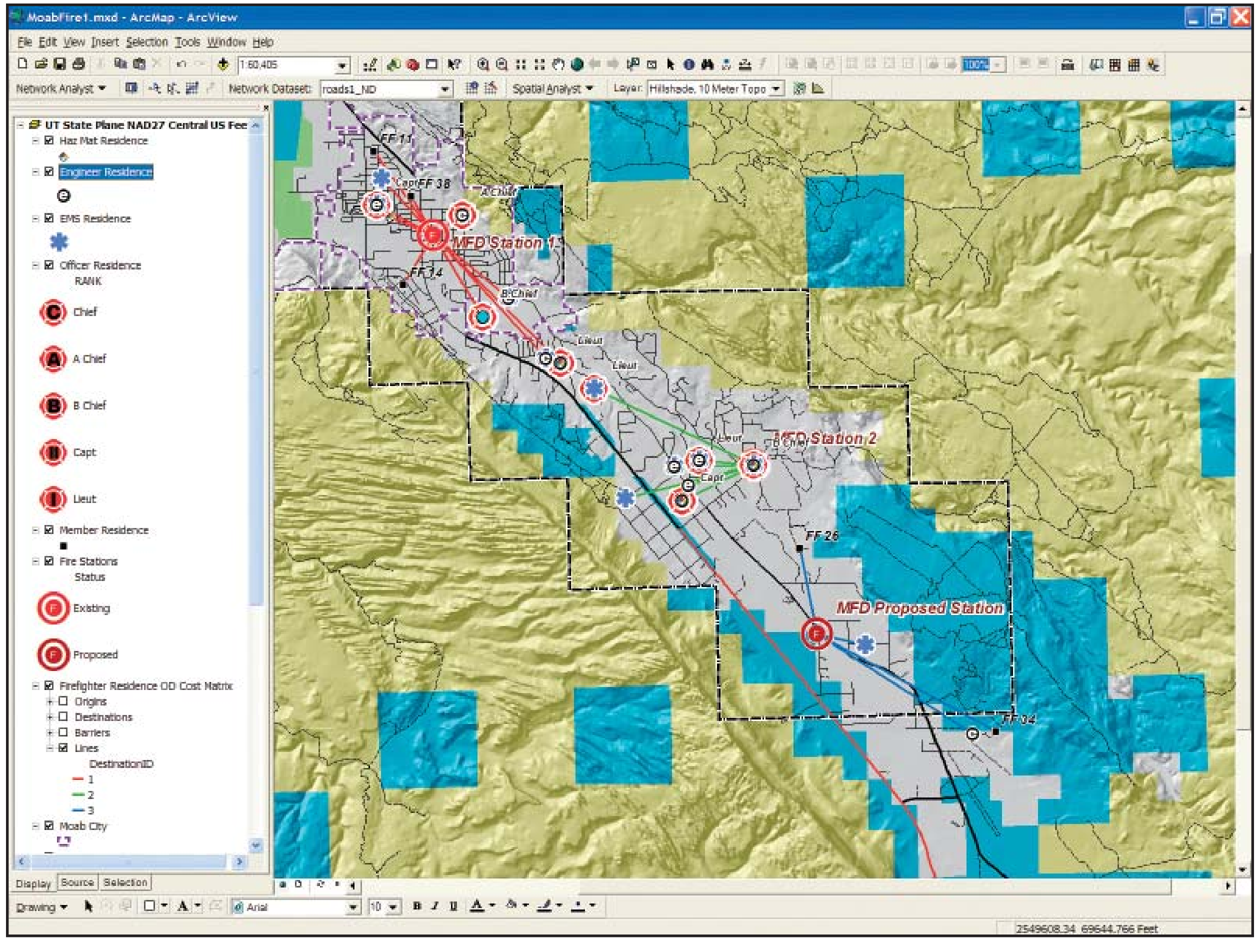
Symbolize the Lines in Firefighter Residence OD Cost Matrix layer to show the connection between each firefighter's home and all stations.

3. To map drive times for POVs requires building a second definition query for the OD Matrix Lines. Create this definition query by using the initial query to produce the expression "Crew_07Q1.A_070106" >0 AND ODLines.DestinationID=1



This map identifies the first four firefighters arriving at Station 1 and the residence location of the weekend officer.

4. Inspect the results and locate FF 22. This officer's drive time is 2.27 minutes over a distance of 1.66 miles. Other responders should arrive at the station ahead of the weekend officer.



This map shows routes to the closest station for all January 6 firefighters. It also shows firefighter status including engineers, EMTs, and hazmat technicians.

5. To map fastest responders, locate the ODLines.Total_Minutes field in the Lines table and sort it in ascending order. Assuming that four firefighters should be on an engine before it responds, manually select the top four records and look at them on the map. The travel time for the fourth arriving firefighter is 2 minutes; 11 seconds is the lag time between the time all firefighters leave

their homes and the arrival time of the fourth crew member. This makes a basic assumption that all firefighters take the same time to react to the call and begin driving their POVs.

Making a Pretty Map and Experimenting with Availability Data

Included in the sample dataset are Layer files to map available fire officers, engineers, firefighters/ emergency medical technicians, and hazmat technicians. Load these Layer files, then relink these layers to the members1.shp. Create your own staffing questions and remap the data.

As a challenge exercise, create tabular joins to Crew_07Q1.dbf and create definition queries for other weekends. Experiment with responses to other stations on different weekends. Pay special attention to the holiday weekends, January 13 and February 17, when a minimum number of staff members are in town and decide if staffing is adequate to handle the wide variety of emergency situations that confront Moab firefighters.

Summary

Moab's Fire Department provides exceptional service to Valley residents, relying largely upon volunteer staff. Dedicated personnel, a high level of training, and careful planning make it all possible. This article demonstrates one use of the Network Analyst OD cost matrix to answer real-world questions. The OD cost matrix has other uses in emergency management that may be the subject of future articles.

(Reprinted from the April–June 2007 issue of *ArcUser* magazine)

Do It Yourself!

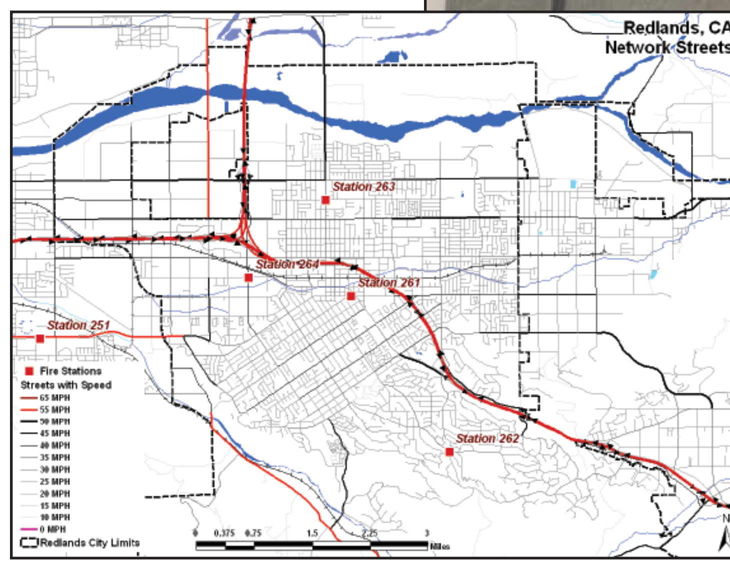
Building a Network Dataset from Local Agency Data

By Mike Price, Entrada/San Juan, Inc.

Tutorials in recent issues of *ArcUser* magazine have showed how to create mapped time- and distance-based travel network models for emergency response applications. Building these models required carefully prepared agency or commercial street data that had been tuned for network modeling.

Many local agencies build and maintain quality street datasets, often designed to support highly reliable geocoding. While these streets can be very current and have great positional accuracy, they are often not built to support time- and distance-based networking. However, in many cases, it is possible to modify these street datasets to support a network model.

This exercise uses a street dataset for Redlands, California, where ESRI is headquartered. The Redlands City GIS streets data was designed and is maintained for address geocoding. After inspecting the data, the exercise explores several methods for modifying a copy of the data for time-based networking. This exercise involves careful heads-up editing. The Redlands street data in the sample dataset has been modified



This exercise explores several methods for modifying street data for use in time-based network modeling.

only slightly so exercise tasks can be accomplished more quickly. It is very similar to the original Redlands street dataset.

This article assumes a basic understanding of ArcGIS Desktop and the ArcGIS Network Analyst extension. To review modeling travel networks with ArcGIS Network Analyst and the concepts of distribution and concentration, please read and work the exercises published in the July–September 2007, October–December 2007, and Summer 2008 issues of *ArcUser* and available online at www .esri.com/arcuser. These articles provide background information on how emergency responders use time as a response measure.

Getting Starting

To obtain the sample dataset for this exercise, visit the *ArcUser Online* Web site at www.esri.com/ arcuser and download redlands.zip. This file contains all the data necessary to perform this tutorial. Unzip this data archive near the root directory on your hard drive. In Windows Explorer, right-click on the Redlands folder; choose Properties; and on the General tab, make sure Read Only is unchecked.

Open ArcCatalog and navigate to the Redlands folder. Preview the data in Geography and Table modes. Notice that the data is in California State Plane North American Datum of 1983 (NAD 83) Zone V and units are U.S. Survey Feet. Preview the Redlands01.mxd file to see the study area for the exercise.

Locate and carefully inspect the streets shapefile. This geocoding dataset was created and maintained by the City of Redlands. To protect the original file, make a copy of streets_in and rename it streets_nw. The copied file, streets_nw, will be used for this exercise.

Adding Fields for Results

While in ArcCatalog, add three attributes to support the network model. Preview the streets_nw attribute table. In the Catalog tree on the left, right-click on streets_nw, choose Properties, and click the Field tab. Notice that the lowermost (rightmost) field in the source table is ADDRCITY. The three new fields will support directional time and distance networking.

1. Click the first blank line in the Field Name column and name the first new field OneWay. Specify the data type as text and the field length as four characters. Click Apply. This field will be used to code travel direction for all one-way streets.

2. Click in the next blank name field and type “Length_Mi.” Specify a Double format with a Precision of 12 and a Scale of 6. Click Apply.When the length of each street segment is calculated in decimal miles later in this lesson, this field will hold those results. These values will be used to calculate travel time for all segments.

3. Add a third field; name it Minutes; and set its type to Double, with a precision of 12 and a scale of 6. This field stores calculated travel times for each segment. Click Apply and OK. Close ArcCatalog.

What You Will Need

- ArcGIS (ArcView, ArcEditor, or ArcInfo license levels)
- ArcGIS Network Analyst extension
- Sample data from ArcUser Online

Examining Distance and Speed, Street Class, Street Type

Start ArcMap, turn on the Network Analyst extension, and make the Network Analyst toolbar visible. Open Redlands01.mxd and verify that all data layers have loaded properly, including the two layers that display the network streets. The Streets with Speed layer will be visible and the Streets with Speed and Direction layer will be unchecked. Double-click on any layers that have a red exclamation point, choose Properties > Source, and click Set Data Source to repair the path to the data.

Switch from Layout View to Data View and open the attribute table for the Streets with Speed layer. Study all the fields for this layer.

Verify that the three new fields are available and contain either zero values or no text. Inspect all fields and look for information that will support geocoding and a time/distance network. This dataset contains speed limit [SPEED_MPH], street class [CLASS], and school zone [SCHOOLZONE] fields that can participate in the network. However, it does not contain any numeric values for distance. The TYPE field provides clues that it contains some directional streets. Select fields where [TYPE] = ‘FRWY’ or [TYPE] = ‘RAMP’ and notice that these records do not contain geocoding attributes. They can be edited without upsetting the geocoding fields.

Impedance—Distance

Notice that there is no distance field in the source dataset. The Length_Mi field added earlier needs to be populated, but before calculating street segment lengths, many of the freeway vectors need to be edited.

Impedance—Speed

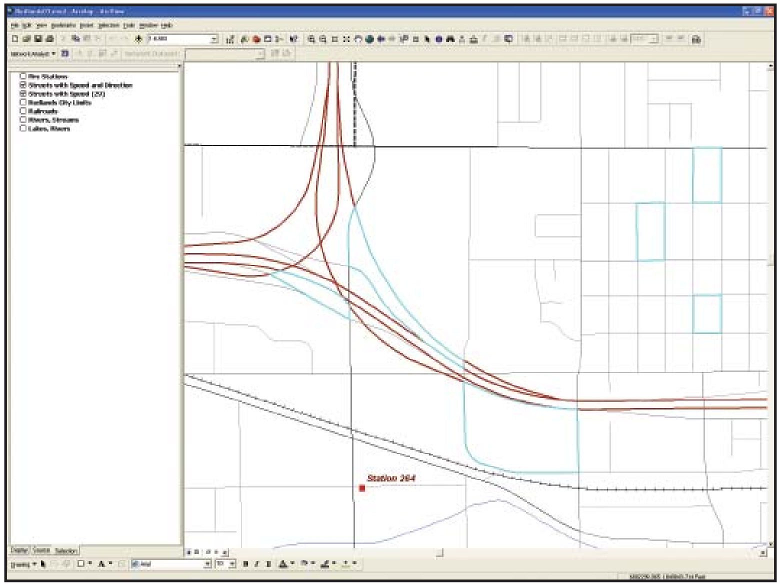
Sort the [SPEED_MPH] field in ascending order and carefully review the values. Notice that nine records have 0 speed limit. Before building the network, these records must be updated or deleted. Just remember that they are now in the street dataset. The [SPEED_MPH] field will provide the primary impedance and a zero speed will not contribute to a meaningful time. Once directionality and connectivity issues are resolved, the segment length in miles and travel time in minutes can be calculated.

Crossing Relationships

Because this is a geocoding dataset, it does not contain fields for nonintersecting crossings (which are also called z-elevations). Although two z-elevation fields could be added to this table, it would require careful editing of all the values for each crossing and intersecting street segment—a complex, time-intensive process. Instead, geometry—not attribution—will be used to define and manage crossing relationships.

Connectivity

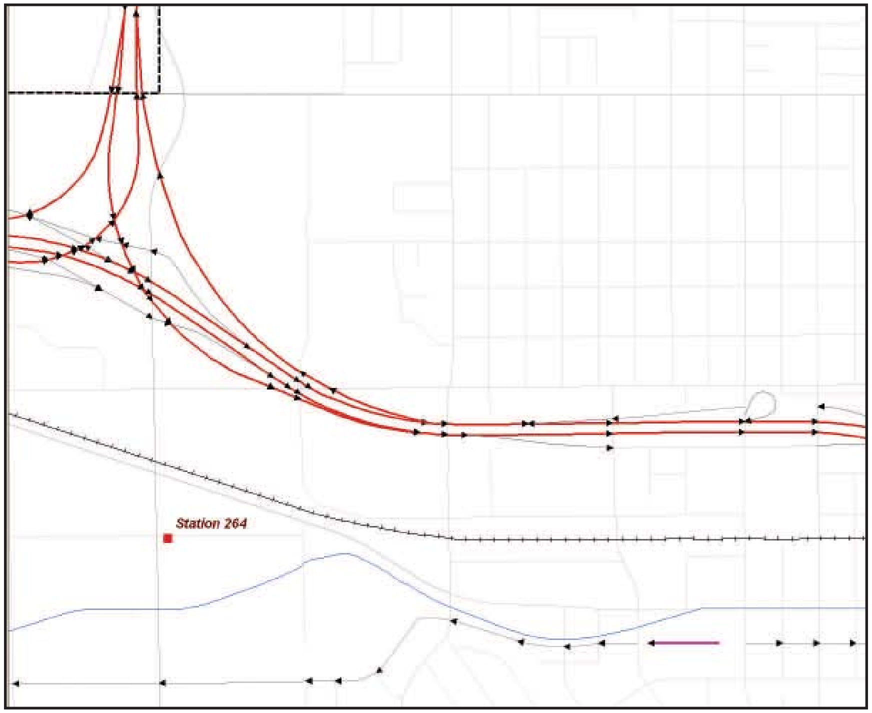
To properly create a network, all street segments must share common endpoints. Make the Streets with Speed layer selectable and zoom in or use the Magnifier Window to inspect intersections. Select street segments to verify connectivity. Notice that even freeway interchanges display connectivity where they cross city streets. Later in the exercise, freeway segments will be spanned across city streets to limit connectivity.



This exercise will limit connectivity by merging freeway segments across city streets. These selected examples show connectivity.

Directionality

Open the Layer Properties dialog box for the Streets with Speed layer, click on the Display tab, and set the transparency for the layer to 70 percent. Turn on the Streets with Speed and Direction layer. Zoom in and inspect streets near the I-10 and I-210 freeway interchange. Study the endpoint arrows and notice that not all segments are properly oriented for right-hand travel. This must be fixed. The OneWay field will be used to code all one-way segments.



Study the endpoint arrows and notice that some segments are properly oriented for right-hand travel, while some are not.

Turns and Turn Relationships

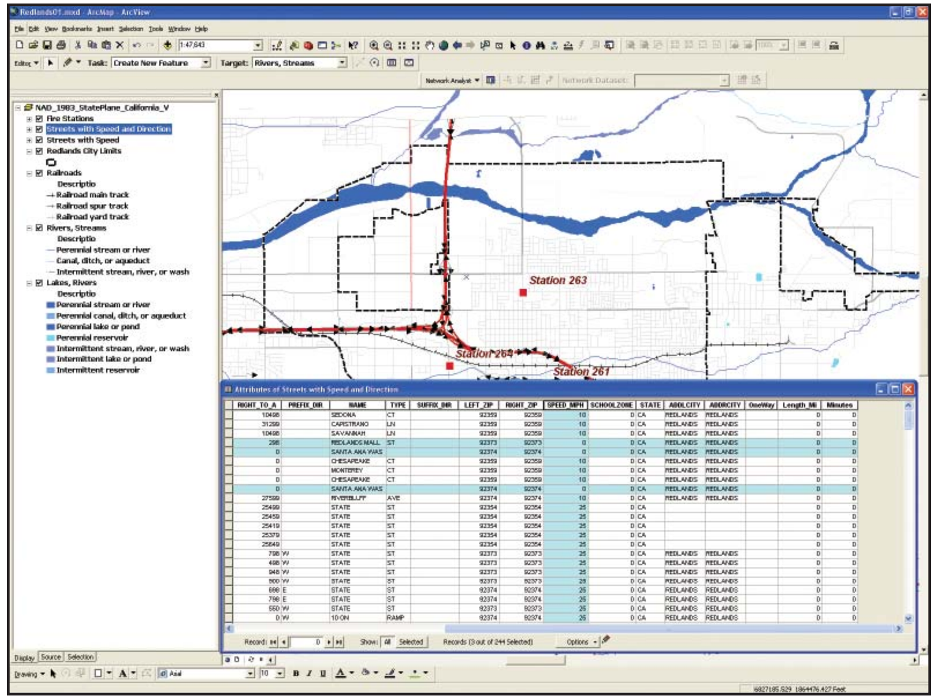
Turns and intersection slowdowns are important in a time-based network. After updating streets in the next section, the next step will be building a network using global turns. Save the Redlands01 .mxd before going on to the next section.

Editing the Streets with Speed and Direction Layer

Open the Editor toolbar by choosing View > Toolbars > Editor, and choose Start Editing from the drop-down to start an editing session. Use the Selection tab in the table of contents to make only the Streets with Speed and Direction layer selectable.

Speed Limits

Open the attribute table for the Streets with Speed and Direction layer and inspect the new fields (Length_Mi, OneWay, Minutes). Locate all records where SPEED_MPH = 0. Zoom to and inspect each record. Decide whether to increase the speed limit or delete the record. If the choice is increasing the speed limit, use 10, 15, or 20 mph.(Hint: Delete Redlands Mall and Santa Ana Wash; set all other speeds to 10 mph.) Save the map document.



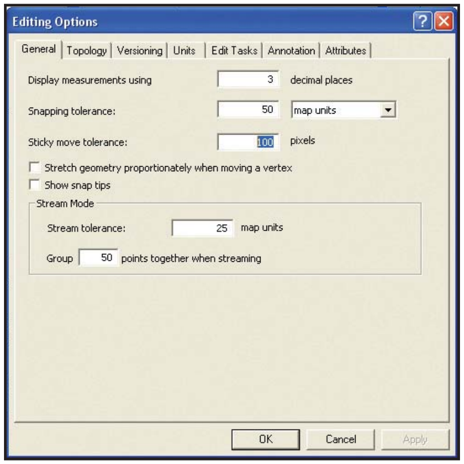
Delete Redlands Mall and the Santa Ana Wash; set all other speeds to 10 mph.

Directionality

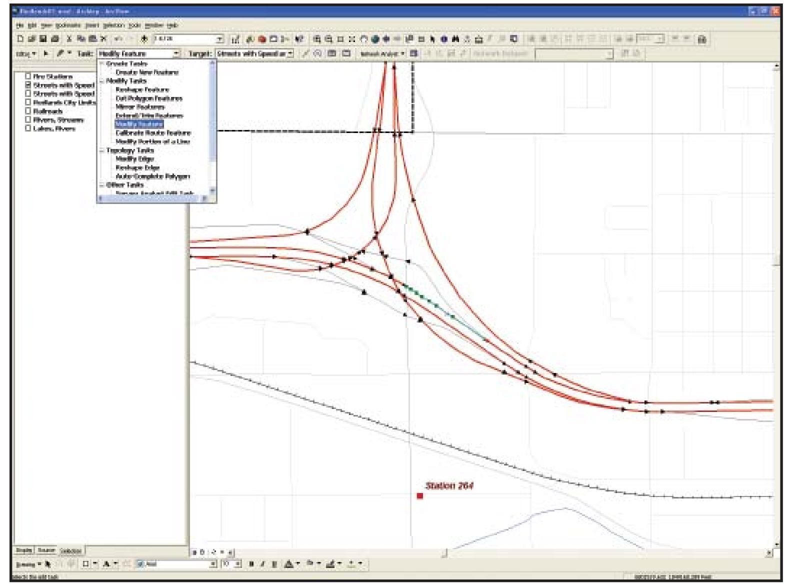
Now to properly orient all freeway and ramp street segments. There are several segments of one-way streets in downtown Redlands that will be validated.

1. Before beginning an editing session, set a sticky move tolerance that will prevent accidentally moving a segment while modifying its orientation. In the Editing toolbar, select the Editing drop-down and open Options. Set the snapping tolerance to 50 feet and the sticky move tolerance to 100 pixels.

2. Close the attribute table for Streets with Speed and Direction and zoom in to the freeway interchange area. Study the segments displaying directional arrows. In the Editor toolbar, set the editing target as the Streets with Speed layer (which is a nonselectable layer) and specify the task as Modify Feature. Select an improperly oriented street segment. Notice that the red node also shows the downstream end of the selected segment.



Set the snapping tolerance to 50 feet and the sticky move tolerance to 100 pixels.

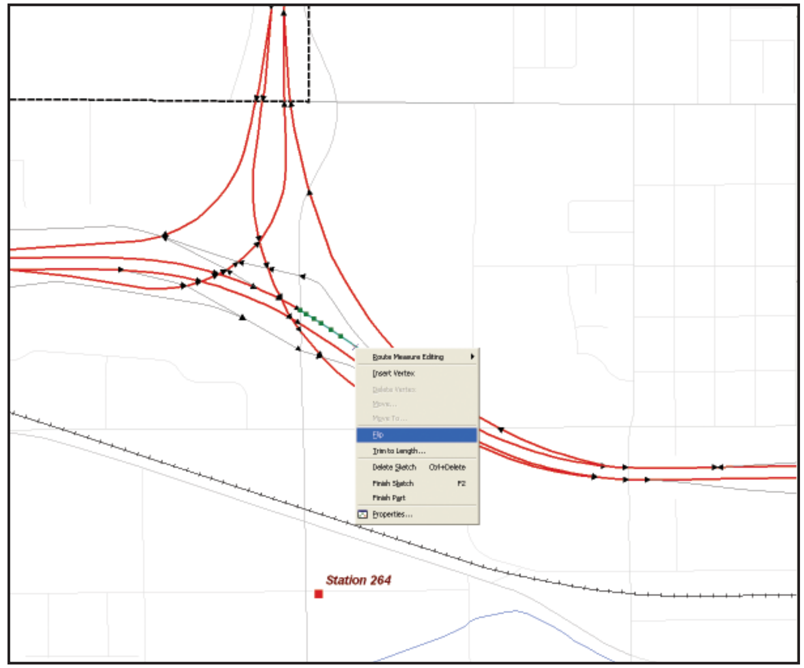


Set the editing target to Streets with Speed and Direction and specify the Modify Feature task. Select an improperly oriented street segment and notice that the red node also shows the downstream end of the selected segment.

3. To flip a segment, verify that the nodes are displayed and select the Edit tool (this tool has a black arrowhead icon and is usually located to the right of the Editing toolbar drop-down).

4. Carefully position the mouse cursor near the line's midpoint. (Hint: Look for the small *x.*)

5. Right-click and select Flip from the context menu. The red leading node swaps ends with the arrow, which indicates the line has reversed direction. Deselect this line.



Carefully position the mouse cursor tip near the line's midpoint. (Hint: Look for the small x.) Right-click and select Flip from the context menu. Watch as the red leading node swaps ends, indicating that the line has reversed direction.

6. Inspect all freeway and ramp segments and flip all improperly oriented segments. Caution: Be careful not to move any segments. If you think that you might have moved a segment, go to the Editor drop-down and choose Undo Move to return the segment to its original location.

7. Save edits about every 10 flips. (Hint: Use the shortcut keys to navigate the map more rapidly: C to pan, Z to zoom in, and X to zoom out.)

8. Check the Task window on the Editor toolbar to be certain that it displays Modify Feature. It will probably take 20 to 30 minutes to flip all segments.

The city streets in Redlands that show directionality are properly oriented. Inspect street segments carefully to ensure this. If you accidentally flip a correct segment, simply flip it back. Check all on-ramps and off-ramps and watch out for a rest area on eastbound I-10. A OneWay code will be assigned to several ramps. Save the edits and the map document.

Crossing Relationships

In the next process, certain freeway and ramp segments will be merged to build correct crossing relationships. Do not perform this step before all appropriate directional segments are properly oriented.

Reopen an edit session and zoom to the I-10/I-210 interchange. Verify that only the Streets with Speed and Direction layer is selectable. Inspect all directional vectors. Use the Select Features tool to individually select several directional vectors.

Because all directional vectors share endpoints with other segments, a network built with these segments would maintain correct one-way travel, but might include segments that would make sharp turns from a limited-access travel lane onto crossing freeways and even city streets. This is not good.

Crossing geometries will help fix this issue. Simply stated, where a limited-access travel lane intersects another class of noncontinuous line segments, the limited-access segments will be merged to create a single crossing element. If two limited-access segments merge into one, which happens with on- and off-ramps, these segments will not be merged.

In the interchange area, study these crossing relationships carefully. Using the Select Features tool, highlight two or more continuous segments that make up a ramp in this area. Do not select any line segments that cross the ramp segments being selected. Zoom in to make certain all segments for that section of ramp are selected. Select elements by beginning at one end of a section of continuous segments and select them in the direction of travel.

In the Editing toolbar, click the Editor drop-down and select Merge. Explore the Merge list and verify that all segments have the same source name. If the Merge dialog box contains more than one feature name, cancel the task and reselect the segments. Click OK to merge the segments and inspect the results.

There should be only one arrowhead, pointing onto I-10 in an easterly direction. Continue the process of merging lzine segments for all ramps that cross in this interchange, including freeway roadways and ramps.

If incorrect segments are accidentally merged, immediately use the Undo button on the standard toolbar to correct this problem. Zoom in and pan as necessary and save the map document frequently.

When all crossing freeway and ramp segments in the I-10/I-210 interchange have been merged to form single crossing elements, follow the rest of I-10 and I-210 and merge all these segments also to create single crossing elements. Watch the directional arrow and the red endpoint symbol while merging segments. If an endpoint lands in the middle of a merged segment, undo the merge, check directionality, and change the segment selected in the Merge dialog box. If segments in an interchange contain speed limit changes, merge only segments with the same speed limit.

Remember not to merge any segments across valid limited-access intersections. Undo the selection immediately to correct any accidental merges. Advanced users can use the Split tool to disconnect segments when needed.

After completing all merging operations, inspect all freeway lands and ramps. Several ramps are problematic. It is difficult to tell if the feature being merged is part of an interchange or part of a crossing relationship. (Imagine how helpful high-resolution imagery would be.) When finished, stop editing, save edits, and save the map document. Now, length for all Redlands streets can be calculated and OneWay attributes can be assigned.

Editing Attributes

Now segment lengths and travel times can be calculated and directionality codes assigned to the OneWay field.

1. Make Streets with Speed and Direction nonvisible, set transparency at 0 for Streets with Speed, and make Streets with Speed the only selectable layer. This layer displays all records in streets_nw.

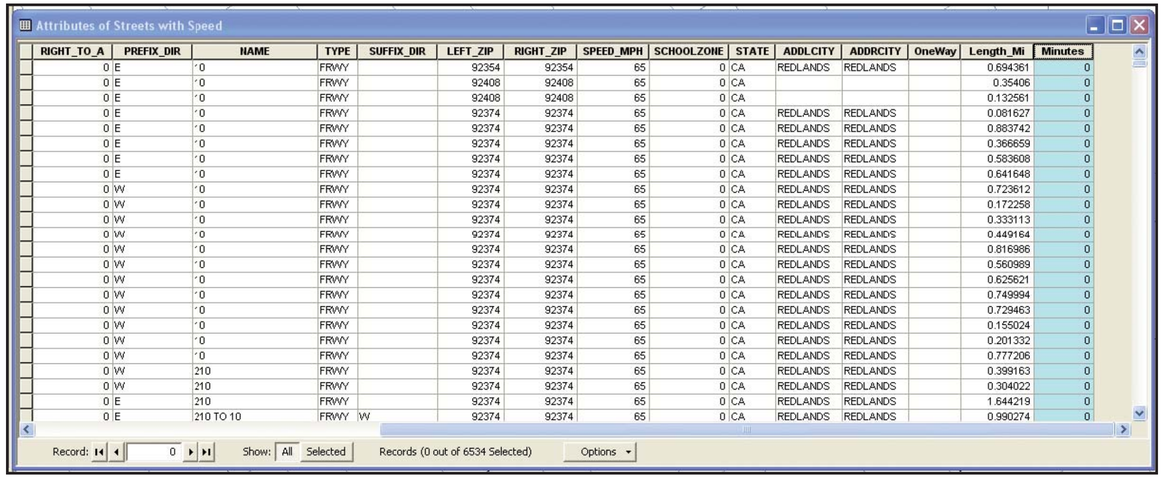
2. Open its attribute table, locate the Length_Mi field, and click on its field header.

3. Select Calculate Geometry and specify Property: Length. Use the coordinate system for the data frame and specify units as Miles U.S. Click OK to calculate all segments.

4. With length in miles, travel time in minutes can now be calculated. Open the Field Calculator. Select the MINUTES field and type

   [Length_Mi] * (60/ [SPEED_MPH])

   in the formula box. Click OK and check the calculations.

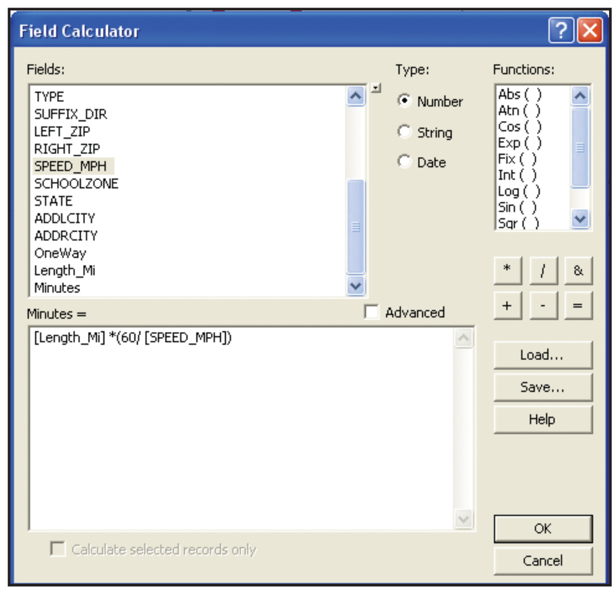


Attributes of Streets with Speed

RIGHT_TO_A	PREFIX_DIR	NAME	TYPE	SUFFIX_DIR	LEFT_ZIP	RIGHT_ZIP	SPEED_MPH	SCHOOLZONE	STATE	ADDLCITY	ADDRCITY	OneWay	Length_Mi	Minutes
0	E	´0	FRWY		92354	92354	65	0	CA	REDLANDS	REDLANDS		0.694361	0
0	E	´0	FRWY		92408	92408	65	0	CA				0.35406	0
0	E	´0	FRWY		92408	92408	65	0	CA				0.132561	0
0	E	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.081627	0
0	E	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.883742	0
0	E	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.366659	0
0	E	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.583608	0
0	E	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.641648	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.723612	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.172258	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.333113	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.449164	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.816986	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.560989	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.625621	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.749994	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.729463	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.155024	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.201332	0
0	W	´0	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.777206	0
0	W	210	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.399163	0
0	W	210	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.304022	0
0	E	210	FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		1.644219	0
0	E	210 TO 10	FRWY	W	92374	92374	65	0	CA	REDLANDS	REDLANDS		0.990274	0

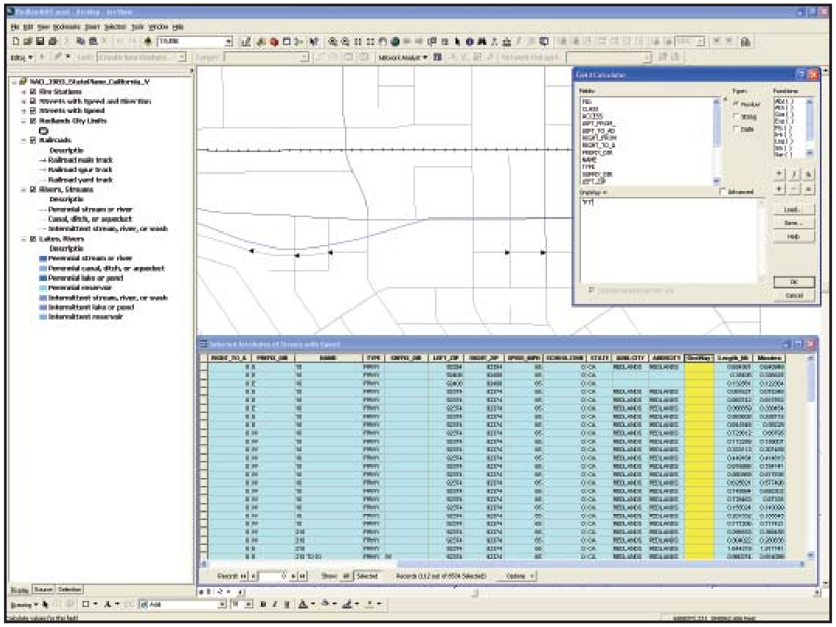
Record: 0 Show: All Selected Records (0 out of 6534 Selected) Options

With length in miles, calculate travel time in minutes.
*Select the minutes field, type [Length_Mi] * (60/ [SPEED_MPH]) in the formula box, and click OK.*



5. Now, assign a OneWay code to all limited-access streets. Close the Streets with Speed attribute table and open the Streets with Speed and Direction attribute table. This layer also references the streets_nw shapefile, filtered to show only limited-access streets and a subset of Redlands streets.

6. Create a query that shows only streets where Type = 'FRWY' or Type = 'RAMP'. Use the Field Calculator to populate the OneWay field for each selected record with the value FT (a code for From-To). Because directionality has been carefully managed for this data, these codes can be applied for all the limited access dataset.

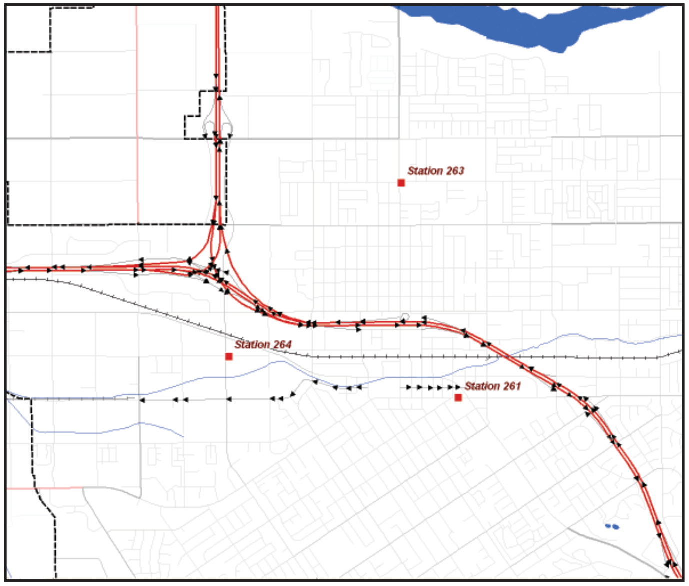


Create a query that shows only streets where Type = 'FRWY' or Type = 'RAMP' and use the Field Calculator to populate the OneWay field with the FT (From-To) code for each selected record.

7. Assign an FT code to five specific Redlands city streets by creating a query where "TYPE" = 'ST' AND "NAME" = 'STATE' AND "PREFIX_DIR" = 'E' AND "LEFT_FROM_" <500. Use Field Calculator again to place an FT code in the OneWay field for these five records.

Redlands streets are now ready to be used for building a time-based network. Zoom to the data extent, save the map document, and admire the project.

The tasks in this exercise might seem a bit rigorous, but these steps were necessary to create a quality network source without compromising the data. Save this enhanced dataset for future activities.



A properly oriented network.

Summary

In previous exercises, the ArcGIS Network Analyst extension was used to model time and distance response from fixed facilities. Experiment with this network street dataset by creating a network dataset from it and using it to work the Routes and Service Areas exercises in previous *ArcUser* articles in this series, noted at the beginning of this article.

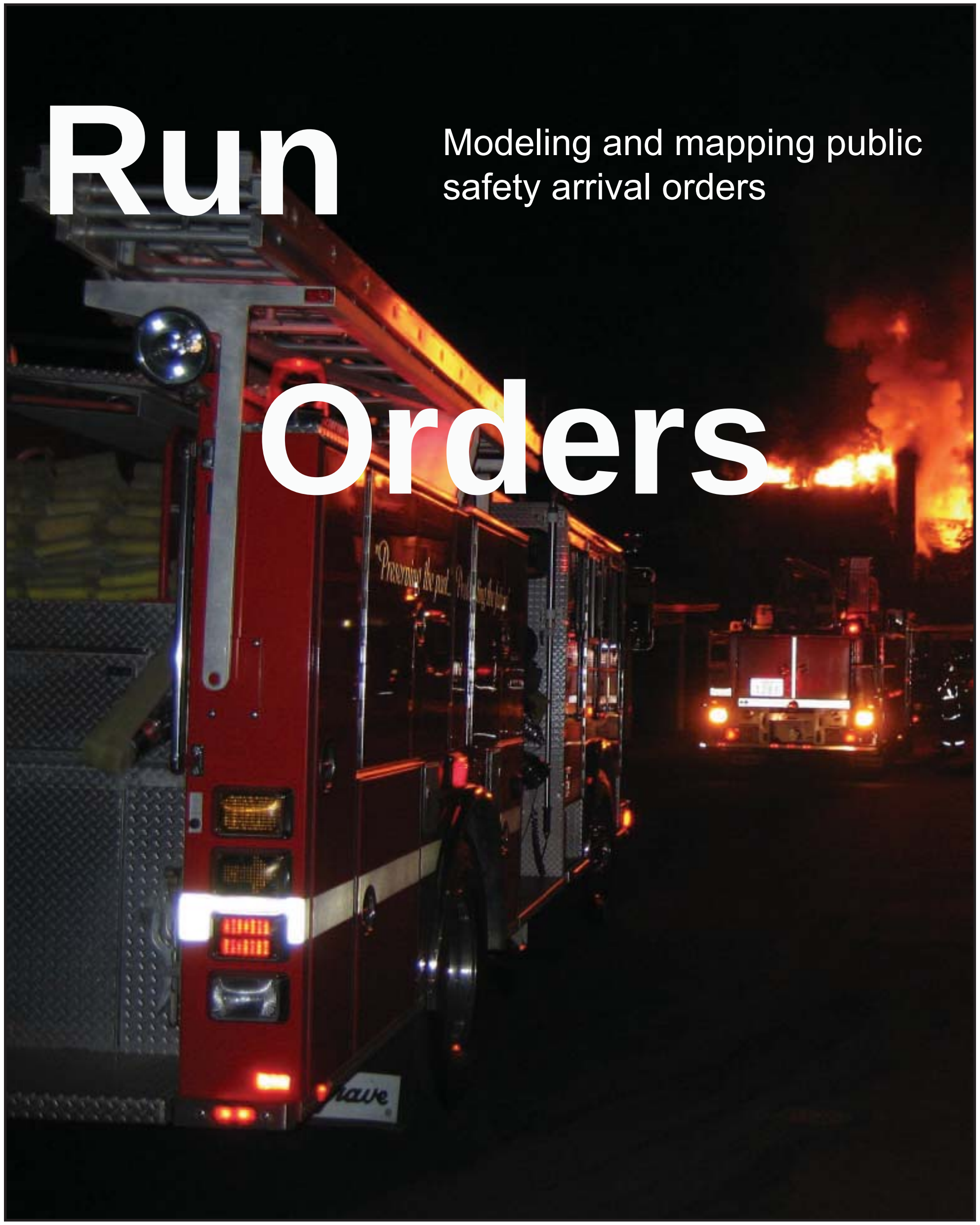
Acknowledgments

Thanks go to Tom Patterson, ESRI public safety specialist, for requesting this exercise and obtaining the Redlands data. Special thanks also go to the Redlands GIS staff members for providing this excellent dataset and allowing me to prepare and use it for this exercise.

(Reprinted from the Summer 2009 issue of *ArcUser* magazine)

Run Orders

Modeling and mapping public safety arrival orders



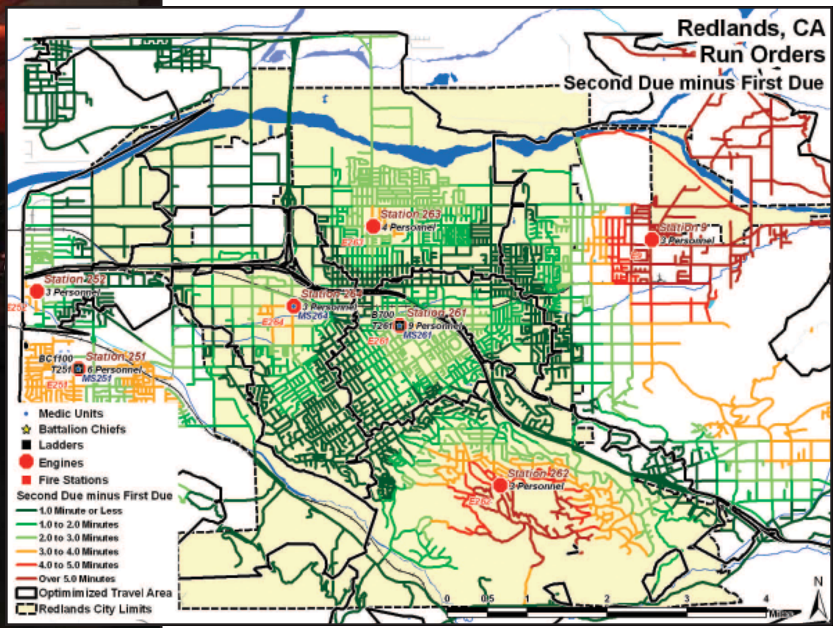
What You Will Need

- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- ArcGIS Network Analyst extension
- Sample data downloaded from ArcUser *Online*
- 500 MB of free disk space

By Mike Price, Entrada/San Juan, Inc.

Timely integrated response to emergencies limits suffering and damage. GIS helps responding agencies provide better service. This is the last in a series of articles, which began in the October–December 2006 issue of *ArcUser* magazine, that have demonstrated how fire departments can model service areas and response using the ArcGIS Network Analyst extension.

Run orders allow a public safety agency to predict and map the arrival sequence and times for responders traveling to an incident from multiple locations. Previous exercises in *ArcUser* used optimized travel areas generated using the ArcGIS Network Analyst extension to identify the station from which the first responders (i.e., First Due) will arrive for a given location.



Run orders model response scenarios. This map shows the approximate time interval that the first crew on scene will wait for the second crew to arrive.

By sequentially remodeling each First Due provider, Second Due coverage areas can also be mapped.

Response modeling beyond Second Due coverage areas has always been difficult. In “Do It Yourself—Building a network dataset from local agency data,” which appeared in the Summer 2009 issue of *ArcUser,* a sample dataset for the city of Redlands, California, was modified so it would support time-based travel modeling with ArcGIS Network Analyst 9.3.

Working this exercise requires a basic understanding of ArcGIS Desktop and the ArcGIS Network Analyst extension. To review modeling travel networks with ArcGIS Network Analyst, including information on distribution and concentration, and to work other exercises in this series, visit the Learn How to Mode Networks page (www.esri.com/news/arcuser/avmodel.html).

This exercise extends the street data that was enhanced in the previous exercise to include information about arrival orders and times for up to five emergency responders. In addition, areas where First Due coverage is within national standards will be identified and backfilled response analyzed when the nearest provider is already on a call. To ensure safe, quick entry into a structure by responders, the time lapse between arrival of the first and second units will be determined.

This tutorial shows how to model and map arrival orders for four fire stations near ESRI’s headquarters in Redlands, two western stations in the nearby city of Loma Linda, and one station to the east of Redlands in Mentone. It involves a complex workflow that includes definition queries, tabular joins, field and geometry calculations, and data exports. It requires great attention to detail.

Instead of using the dataset produced when working the 2009 Summer issue exercise, use the sample dataset for this tutorial available from *ArcUser Online.* It has been converted from shapefiles to a file geodatabase and contains several additional fields that support run orders, and the network dataset used will be built inside a geodatabase feature dataset. Even though the sample dataset is small, you will need at least 500 MB of hard drive space to complete this exercise. Also note that the Closest Facility solution is complex and will take some time to solve.

Getting Starting

Download the sample dataset, Redlands.zip, from *ArcUser Online,* which contains all the data necessary to perform this tutorial. Unzip Redlands.zip near the root of your project folder and open its contents in ArcCatalog. Navigate to the Redlands folder, expand the Redlands_Fire geodatabase, and preview the Run_Order_Model feature dataset in Geography and Tablemodes. As in the previous exercise, the projected coordinate system is North American Datum (NAD) 1983 California State Plane Zone V, and the unit of measure is the U.S. Survey Foot.

Preview the feature class named Network_Streets, as shown. Notice this street data is very similar to the street data used in the exercise in the last issue. With Network_Streets selected, switch to table view and explore the table structure. Scroll to the fields on the right side and note the new fields: INDEX, CENT_X, CENT_Y, STAT_01, and TIME_01. All fields contain zero values but they will soon be populated with the arrival order and times for the five closest stations.

Building the Network Dataset

The next step is building the Redlands Network_Dataset in ArcCatalog.

1. Right-click on Run_Order_Model and select New > Network Dataset. Accept the default name, Run_Order_Model_ND, for this feature class.
2. Continue through the Network Dataset wizard, accepting defaults until you get to the wizard pane for specifying attributes for the Network Dataset. With Minutes selected, click the Add button. In the New Attribute dialog box, add a new attribute named Length_Mi and set its units to Miles and the Data Type to Double. Click OK.
3. Reselect Minutes. Click the Evaluators button and select the Default Values tab. Right-click the Turn and choose Type > Global Turn Delay. Click Apply.
4. Press F12 to open the Global Turn Delay Evaluator and type in the delay parameters shown in Table 1. Click OK and OK again to return to the dialog box for specifying attributes.
5. Click Next to continue and accept the directions defaults.
6. Click Next, select the summary text, copy and paste it to a WordPad document, and save that document with the project.
7. Click Finish and build the network. Inspect it when ArcCatalog has finished processing.

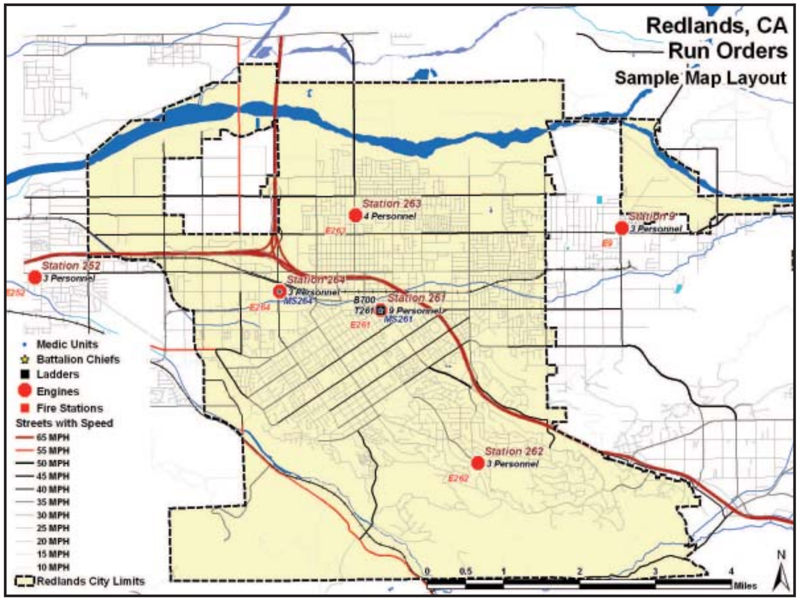
Creating Indexes, Generating Centroids, and Exporting Data

1. Close ArcCatalog and open ArcMap. Navigate to the \Redlands folder and open Redlands01 .mxd. Switch from Layout View to Data View.
2. Open the attribute table for the Streets with Speed layer. Scroll to the right, study the fields, and locate the INDEX, CENT_X, and CENT_Y fields.
3. Right-click on INDEX and open the Field Calculator. Double-click on OBJECT_ID1 to add it to the formula box. Click OK to populate this field with a sequential index.

4. Right-click on the header for CENT_X and select Calculate Geometry. Choose X Coordinate of Centroid to perform this calculation. Use the data frame coordinate system (NAD 1983 StatePlane California V FIPS 0405) and Feet US as the units for this project. Click OK.

5. Repeat this procedure for CENT_Y to calculate values for the Y Coordinate of Centroid field. Inspect the calculations and save the project.

6. Now, export this table to a dBASE file so these points can be used to map street centroid points. In the Attributes of Streets with Speed table, click the Options button and select Export. Specify All Records and save the table in the \Redlands\ DBFFiles folder as Network_ Street_Centroids_XY.dbf. Click on the Source tab of the table of contents (TOC) and add the table to the map.

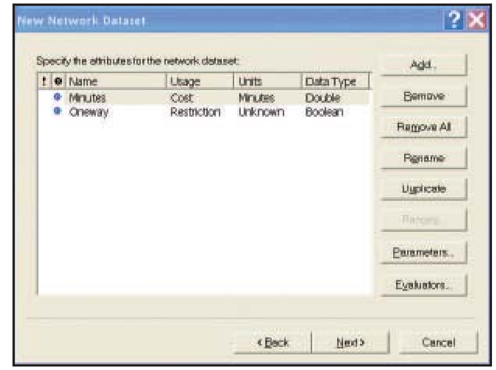


This tutorial models response from fire stations in and near ESRI's headquarters in Redlands, California.

Direction	Description	Seconds
Straight	From Local to Local Road across No Roads	0
Straight	From Local to Local Road across Local Road	1
Reverse	From Local to Local Road	30
Right Turn	From Local to Local Road	2
Left Turn	From Local to Local Road	4

Table 1: Delay parameters.

Specify another attribute for the network dataset called Length_Mi. With Minutes selected, click the Add button and set its units to Miles and the Data Type to Double.



Mapping Incidents

The ArcGIS Network Analyst extension Closest Facility solver requires two input datasets: Locations and Facilities. To build run orders, load Fire Stations as Facilities and the street segment centroids as Incidents. Determining the five closest facilities to each centroid Incident will involve considering seven possible Facilities and almost 6,500 Incidents, so this model might take some time to run. On the Source tab of the TOC, right-click on Network_Street_Centroids_XY.dbf and select Display XY Data. In the Display X,Y dialog box, set the X Field to CENT_X and the Y Field to CENT_Y. Click OK. After processing is complete, open the Network_Street_Centroids_XY.dbf and inspect the location of these centroid points. Save the project.

Loading Facilities and Incidents

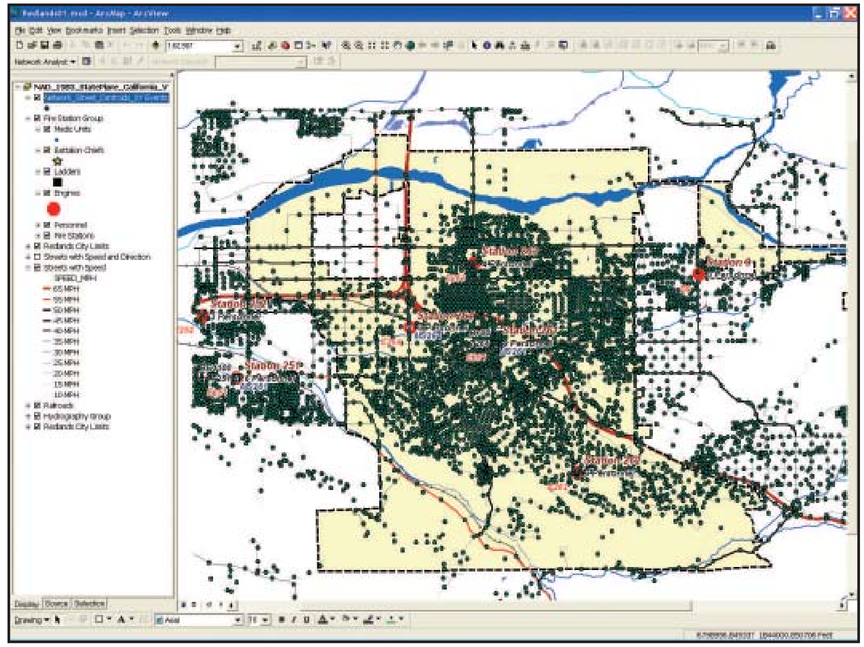
With the XY event theme created, it is time to add the network dataset, load Facilities and Incidents, and define the Closest Facility rules.

1. If necessary, make the Network Analyst extension active, load its toolbar, and open a Network Analyst window.

2. Click the Add Data button and navigate to the Run_Order_Model_ND, located in the Run_Order_Model feature dataset, and add it. Don't add all the feature classes that participate.

3. In the TOC, place Run_Order_Model_ND just below Streets with Speed layer and make it not visible.

4. Click the Network Analyst drop-down and select New Closest Facility. The Closest Facility group is added at the top of the TOC and the Network Analyst window. In the TOC, move the Closest Facility to a location just above the Redlands City Limits layer at the bottom of the TOC.



Use the Network_Street_Centroids_XY.dbf to create an XY Event layer that will be the input for Incident Data needed when calculating Closest Facility.

5. In the Network Analyst window, right-click on Facilities and select Load Locations. Specify Fire Stations and Load From source. Carefully apply the loading parameters listed in Table 2 and click OK. Save the project.

6. Right-click on Incidents and choose Load Locations. Carefully apply the loading parameters listed in Table 3 and click OK. This may take considerable time, so be patient. If the process hangs, close ArcMap, reopen the last saved project, and load it again. Inspect the loaded incident data. If it is correct, save the project again.

Defining the Closest Facility Solver Parameters

1. In the TOC, right-click on Closest Facility layer and choose Properties.

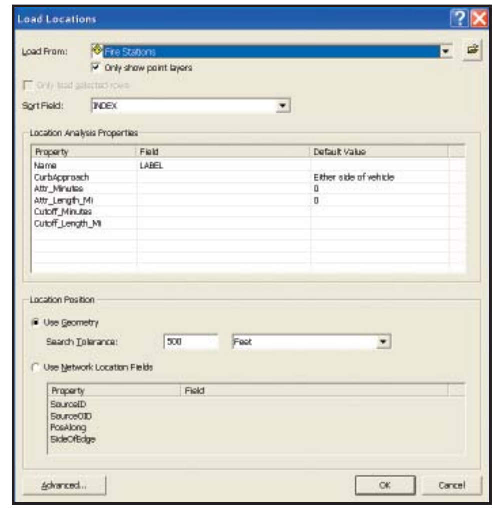
2. In the General tab, rename it to Run Order Closest Facility. In the Analysis tab, set Impedance to Minutes, Default Cutoff Value to 20, and Facilities to Find to 5. Change Travel from to Facility to Incident. Accept defaults for all other parameters.

Parameter	Value
Load From:	FireStations
Sort Field:	INDEX
Location Position:	Use Geometry
Name (under Location Analysis Properties):	LABEL
Search Tolerance:	500 Feet

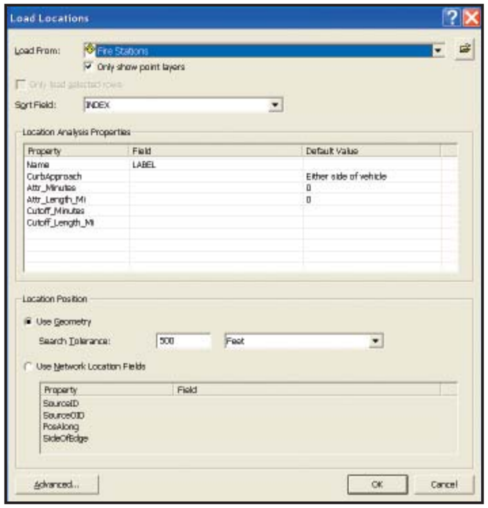
Table 2: Facilities loading parameters.

3. In the Accumulation tab, check the Length_ Mi and Minutes attributes. Click Apply to save these parameters. Click OK. Save the project. In the TOC, right-click on Closest Facility and choose Solve. Now it's time to take a break. There are literally thousands of routes in this solution so this process may take more than 20 minutes. Close Warning Message that lists the centroid points not reached in 20 minutes. Once the process has finished, save the project.

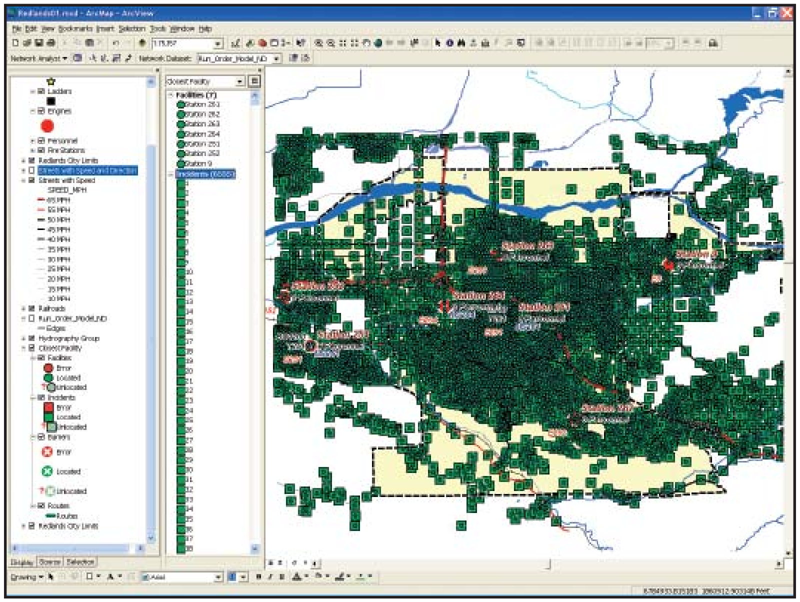
4. Open the Routes table. If it contains approximately 32,000 routes and everything else looks OK, save the project again. The ArcMap document has just increased in size from about 2 MB to more than 100 MB.



Carefully fill out the dialog box when loading Fire Stations for Closest Facility analysis.



Carefully fill out the dialog box when loading the Network_Street_Centroids_XY.dbf for Closest Facility analysis.



Be patient while several thousand centroids load.

Joining Station Information to Each Route

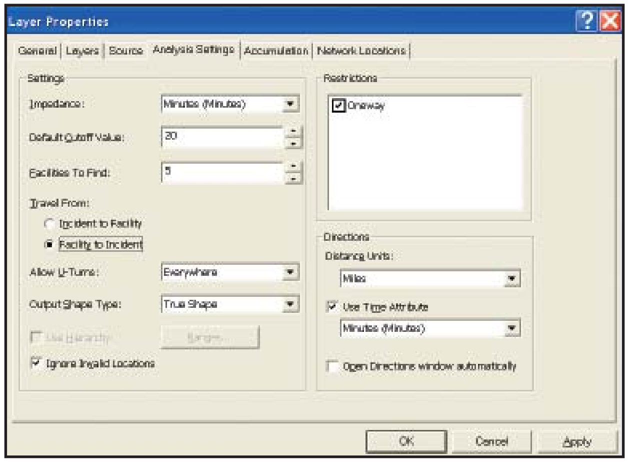
Carefully study each field of the Routes attributes. This data will be used to build run orders for each street segment. Notice that the FacilityID field corresponds to the Index field in the Fire Stations table. The IncidentID field connects to the Streets Index. The FacilityRank lists arrival order, and Total_Minutes contains the travel time for each station to each centroid. Open the Fire Stations table and place it above the Routes attributes.

1. Before exporting arrival data for First through Fifth Due, join station names, apparatus, and personnel to each route.

2. To join Fire Station data to the Routes, right-click on Routes in the TOC and select Join.

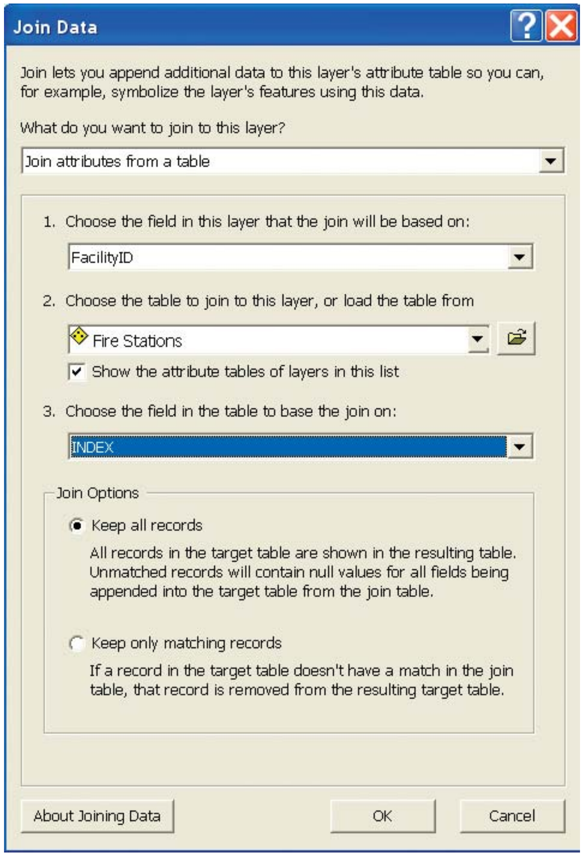
Parameter	Value
Load From:	Network_Street_Centroid_XYEvents
Sort Field:	INDEX
Location Position:	Use Geometry
Name (under Location Analysis Properties):	LABEL
Search Tolerance:	500 Feet

Table 3: Incident loading parameters.



Carefully set the Closest Facility Solver parameters.

3. In the Join Data dialog box, choose Facility ID as the field in this layer that the join will be based on, choose Fire Stations as the table to join to the layer or load the table from, and choose INDEX as the field in the table to base the join on and choose Keep all records.



Join the filtered dBASE files to the Street with Speed layer to calculate values, then remove the join.

4. Click OK, allow indexing, and inspect the Routes table.

With the Station Number (STATION_N) for up to five responders for each modeled street segment, the next step is the crux of this entire procedure.

Exports and Joins

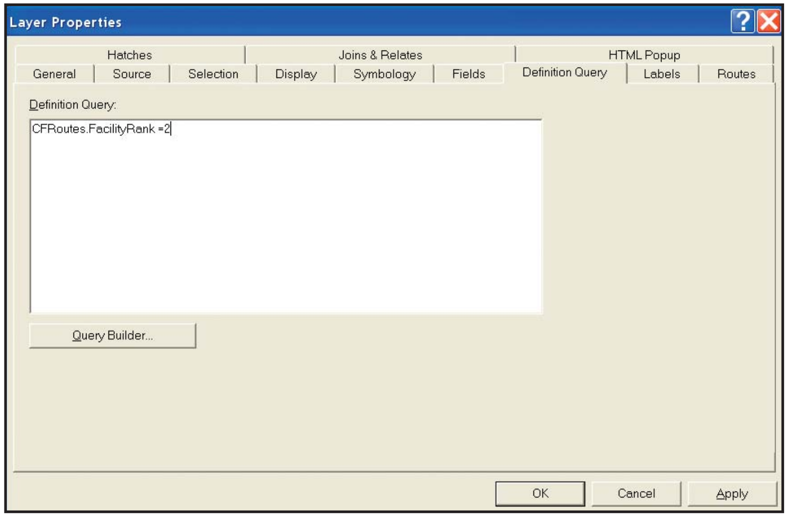
Now to export the five tables, one for each arrival order, individually join each table to the streets, and calculate station and travel time for each arrival. After successfully joining Routes to Fire Stations, the next step is to apply a definition query to filter the Routes attributes by arrival and export each subset to a separate dBASE table.

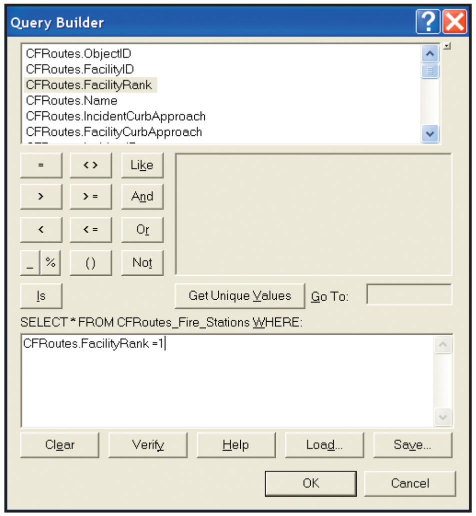
1. In the TOC, right-click on Routes and choose Properties. Click the Definition Query tab. In the formula box, request all records where CFRoutes.FacilityRank = 1. This subset represents travel records for first-on-scene stations. Times should be short, especially near fire stations.

2. The next step is to export the First Due records. In the filtered Routes attribute table, click Options and select Export. Save the exported table to Redlands\DBFFiles and name it RO_01 .dbf. Do not add the table to the map yet.

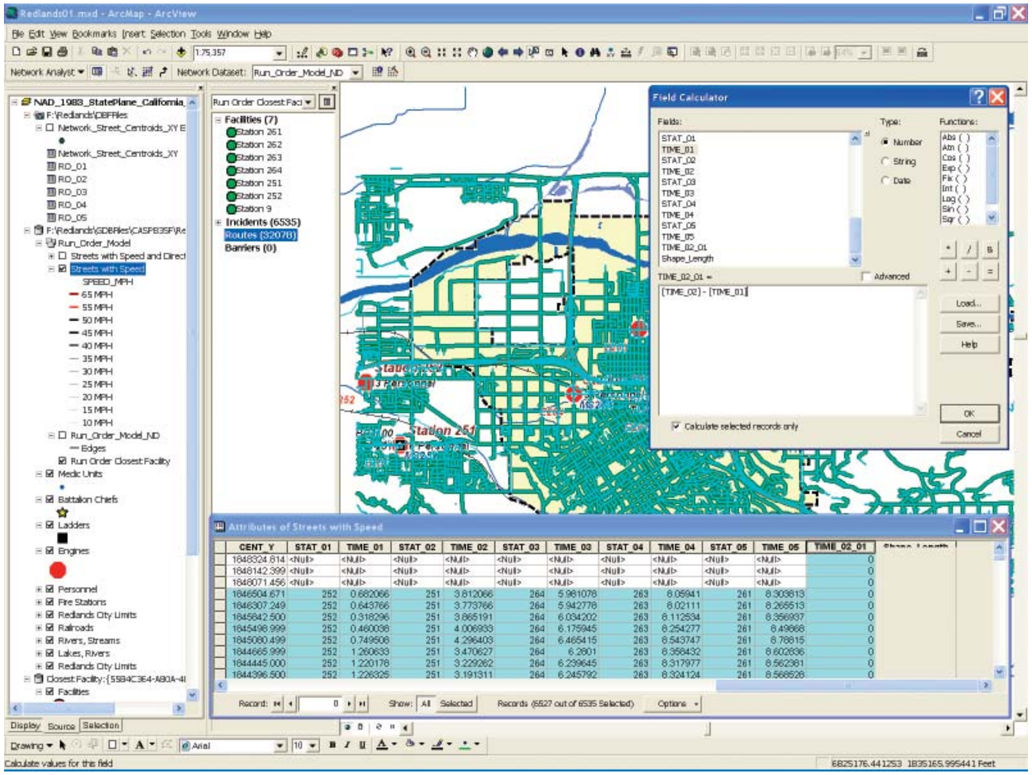
3. Reset the definition query to CFRoutes. FacilityRank = 2 and export again, saving as RO_02 .dbf. Again, don't add the table to the map.

4. Repeat this procedure for RO_03, RO_04, and RO_05. Now, add all five RO files to your map. Save the project again.





In the TOC, right-click on Routes and select Definition Query. In the formula box, request all records where CFRoutes.FacilityRank = 1.



Use the Field Calculator to calculate the delay time between First Due and Second Due.

Populating Station and Time Fields with Joined Table Data

The final analytical steps include five separate joins, each followed by two quick calculations. Perform each operation carefully and check the data!

1. Open and inspect the attribute table for Streets with Speeds. Locate the STAT_01 and TIME_01 fields. Open and position RO_01.dbf below the streets attributes.

2. Right-click on Streets with Speed layer in the TOC and select Joins and Relates. Verify that there are no active joins for this table. (If there are any joins, remove them.) Next create a Join with RO_01, using INDEX as the Streets with Speed join field, RO_01 as the table to join, and IncidentID as its join field. Click OK to continue. Do not index this table. Open the table and verify the join.

3. In the joined table, navigate to STAT_01 and right-click its header. Select Field Calculator and populate the RO_01.STATION_NO field with values from Network_Streets. STAT_01.

4. Next, use the Field Calculator to populate the TIME_01 field with the values from the RO_01 .Total_Minu field. Check the work. Null records represent streets that were not traversed within 20 minutes.

5. ***Now for a really important step. In the TOC, right-click Streets with Speed, select Joins and Relates, and remove the RO_01 join. Do not skip this step.***

6. Create new joins on Streets with Speed to the other RO tables using INDEX as the field the join is based on, the RO table (e.g., RO_02, RO_03), and IncidentID as the field in the table to base the join on. Populate the station (STAT_0x) using the formula Header = STAT_0x, the field to populate = Network_Streets.STAT_0x, and the value to use is RO_0x.STATION_NO. Populate the arrival time fields using the formula: Header = TIME_0x, the field to populate = Network_ Streets.TIME_0x, and the value to use is RO_0x.Total_Minu. Be sure to remove the join each time.

Calculating Delay Time

Now, calculate the delay time between arrival of the first and second responders. A fire engine typically includes three or four firefighters. To safely conduct rescue and initial interior operations, more firefighters are often needed. Subtracting the First Due arrival time from the Second Due time will produce the approximate time interval between when the first on-scene crew arrives and a second crew arrives. Right-click on TIME_02_01 and choose Field Calculator. Enter the formula [TIME_02] – [TIME_01] in the formula window and click OK. Inspect this calculation and save again.

Mapping Run Orders—The Bonus Round

Now it is time to make some maps. The Redlands folder in the sample dataset contains a Bonus folder with several Layer files for symbolizing the various responders (First Due, Second Due, etc.). Load all these Layer files and create a Group Layer for them named Run Order Group. Place the group just below Fire Stations in the TOC. Collapse the legends for Second, Third, Fourth, and Fifth Due.

Notice that data links to all Run Order layers are missing. To fix this, right-click on First Due in the TOC and choose Data > Repair Data Source. Navigate to \GDBFiles\CASP835F\Redlands_Fire .gdb and select Network_Streets inside the Run_Order_Streets feature dataset. Fix all layers in the Run Order Group in a similar manner. Turn off all Run Order layers except First Due. Switch to Layout View and study the colors. These First Due polylines seem to cluster around their home stations.

Verifying Relationships

To verify First Due relationships, click Add Data and navigate to \Bonus_Files\SHPFiles\CASP835F and load Optimized Travel Area.lyr. Place it at the top of the Run Order Group. This response area optimization was built from the same Redlands Streets using the functionality in Network Analyst to optimize service areas. Notice the alignment of First Due Streets and optimized response area boundaries, providing visual confirmation of the First Due run orders.

Turn off First Due and turn on Second Due. Look closely at the home area for Redlands Station 261 and observe how Station 264 arrives second from the west, 263 comes in from the north, 262 fills in from the south, and Mentone 9 just reaches the eastern response area for Station 261 as Second Due. Check the Third, Fourth, and Fifth Due layers.

Finally, let's map the arrival time difference between First and Second Due. Turn off all Due layers and make the Second Due minus First Due layer visible. Study the color relationships. Green lines represent short time intervals and red lines represent long intervals. Notice the large time differences for each station are in closest proximity to that station.

Study the attributes to understand that the green lines in fringe areas are not entirely good. Even though the arrival difference is small, the First Due times often exceed five minutes. Look inside the City of Redlands. The time difference throughout much of the populated city is small, except in the most southern areas near Station 262 where all supporting responders must come from the north.

As a bonus exercise, create thematic legends for all layers in the Run Order Group and design a separate map for each. Load these maps into Microsoft PowerPoint to create an informative slide show.

Run Order Benefits and Limitations

Run orders provide emergency responders with an accurate, reliable way to model complex responses with travel from multiple locations. This workflow counts on response from fixed facilities with all responders who are dispatched simultaneously. This method works well for a static, districtwide model that includes automatic and mutual aid. As mobile dispatching and automated vehicle locators (AVL) become widely deployed, this workflow will need to be simplified to speed up individual event dispatching.

In more complex scenarios, appropriate lag times are applied to manually requested resources and volunteer responders to reflect additional time necessary for their departures. Also, unavailable units may be removed from the response stack. Apparatus types and personnel counts may also be included. As a word of caution in rural areas: when modeling long stretches of country roads, be sure to break street segments into appropriately short intervals.

Acknowledgments

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For More Information

Take the ESRI instructor-led course *Working with ArcGIS Network Analyst.*

(Reprinted from the Fall 2009 issue of *ArcUser* magazine)

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