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# Fire Mapping

Building and Maintaining Street Networks in ArcGIS

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To do the exercises and assignment in this book, you need to have ArcGIS Desktop 9.3 software and the ArcGIS Network Analyst 9.3 extension installed on your computer.

The first chapter's exercise was built using version 9.2 of the software.

# Slopes, Sharp Turns, and Speed

Refining emergency response networks to accommodate steep slopes and turn rules

By Mike Price, Entrada/San Juan, Inc.

Exercises in previous *ArcUser* issues demonstrated how the ArcGIS Network Analyst 9.2 extension can be used to model essential services provided by existing and proposed fire stations in King County, Washington. In this issue, the area modeled is farther north—the city of Burnaby, British Columbia, Canada. This exercise will model optimized response areas for a fire department that have been optimized to include time-based travel penalties for steep slopes and sharp turns.

## The Slope/Turns Exercise

The challenge in this exercise is to build the street dataset to display slope in percent for the Burnaby Fire Department's service area. The department is building a new fire hall. Fire Hall 7 will serve a large area in central and western Burnaby. Burnaby's irregular terrain includes slopes of more than 15 percent. To properly model time-based travel, a slope correction factor for steep streets was developed and field-tested. The slope adjustment, together with global turn rules, was applied to posted speed limits to calculate valid travel times and define optimal response areas.

## Introducing Burnaby

Originally a rural agricultural area, Burnaby, British Columbia, received city status in 1992 and has developed into a major business, residential, and transportation corridor between Vancouver and British Columbia's Lower Mainland. With a population of 202,799 (in 2006) and an areal extent of nearly 100 kilometers, Burnaby is the third largest urban center in the province. It is bordered by the Burrard Inlet on the north and the Fraser River to the south. Burnaby's landscape is characterized by hills, ridges, valleys, and an alluvial plain. Elevation ranges from mean sea level to 375 meters. Land features have controlled and constrained development throughout this community.

The Burnaby Fire Department serves the entire municipal area and provides aid response into neighboring jurisdictions. The department staffs six fire halls, and a new station will open soon. The first line of response includes six first line engines, four ladders, a command unit, rescue truck, an equipment truck, and other specialized equipment. The agency's fire suppression and administrative staff numbers 286. In 2006, the department responded to 13,400 calls. The Burnaby Fire Department works closely with the city's excellent Engineering Department to plan and optimize service throughout the area. Burnaby Engineering uses ArcGIS Network Analyst to optimize response areas.

### What You Will Need

- ArcGIS Desktop 9.2 (ArcInfo, ArcEditor, or ArcView license level)
- ArcGIS Network Analyst 9.2 extension
- [Sample data from ArcUser Online](#)

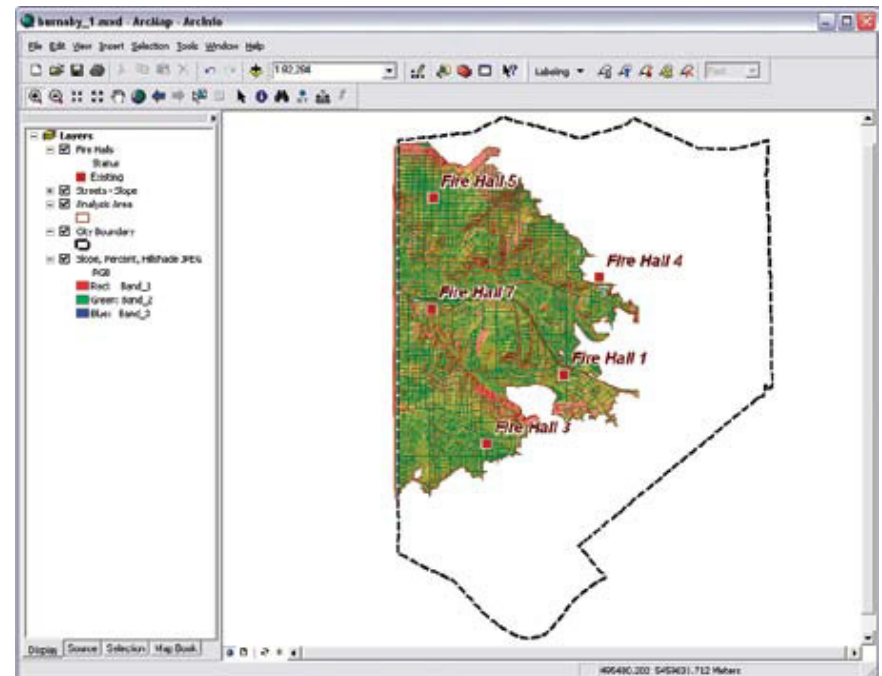
## Getting Started

Download the zipped sample dataset for this exercise from *ArcUser Online* ([esri.com/arcuser](http://esri.com/arcuser)) and place it near the root of the drive that houses the project. Unzip the data and explore it in ArcGIS ArcCatalog. Note that the sample data is contained in a file geodatabase. The geodatabase includes a special feature dataset named *Transportation\_Model* that contains a single feature class named *Highways\_Streets*. This feature class will support time-based modeling. Study the geodatabase layer files for symbolizing municipal boundaries, fire stations, hydrants, and historic incidents and the registered JPEG and its layer file.

This exercise will model detailed slope derived from a large triangulated irregular network (TIN) model. Because the actual background TIN is too large to easily download, a picture of hillshaded slope (*Slpp\_300.jpg*) will be used instead to emphasize steep areas.

Start ArcMap, open a new, blank map document, and save it as *Burnaby1.mxd*. Load the *City Boundary.lyr* from *\Burnaby*

*\GDBFiles\UTM83Z10\*. Check the layer's coordinate system and load *Analysis Area.lyr*, *Streets – Slope.lyr*, and *Fire Halls.lyr* from this same folder. Note that *Streets - Slope* has been thematically symbolized. From *\Burnaby\JPGFiles\UTM83Z10\*, load *Slope, Percent, Hillshade JPEG.lyr* and move it to the bottom of the table of contents (TOC). Ignore the warning box about the spatial reference.



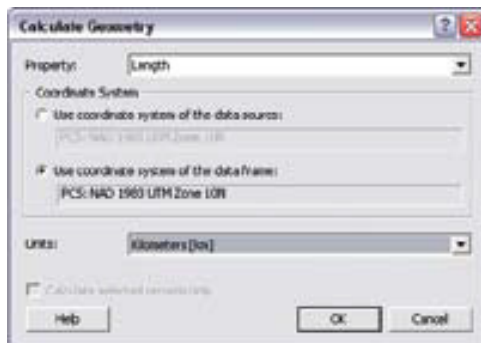
After downloading and unzipping the sample dataset, load *City Boundary.lyr*, *Analysis Area.lyr*, *Streets – Slope.lyr*, and *Fire Halls.lyr*, and the JPEG image of a hillshade.

## Preparing the Street Data

Open and inspect the attribute table for Streets - Slope. Eight fields in this table contain zero (0) values. Before the slope can be depicted, values for the LENGTH\_KM, MINUTES\_R, SLOPE\_ABS, SLOPE\_ADJ\_1, MINUTES\_S, and SPEED\_ADJ1 fields will be calculated.

The values for these fields will be calculated outside an editing session. If a field requires recalculating, simply zero out the field. Right-click on the field header, choose the Field Calculator, select the field name to zero out, input "0" into the text field, and click OK.

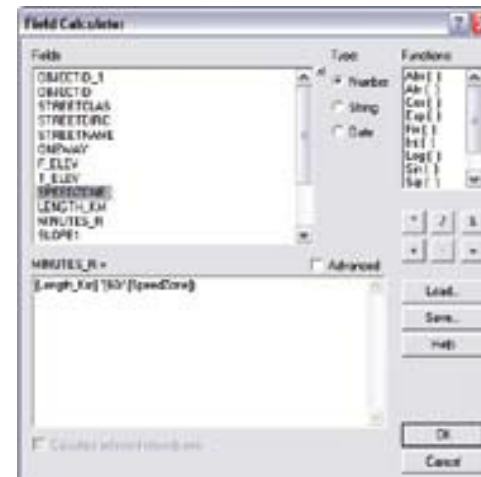
1. Locate LENGTH\_KM field and right-click on its header. Select Calculate Geometry to calculate length of all street segments in kilometers. In the Calculate Geometry dialog box, set the Property as Length, the Coordinate System to Use Coordinate System of the Data Frame, and Units as Kilometers and click OK.



Use Calculate Geometry to calculate all the street segments in kilometers.

2. To calculate the unadjusted travel time, right-click on MINUTES\_R and choose the Field Calculator. In the Field Calculator text field, input the following equation and click OK.

$[Length\_Km] *(60 / [SpeedZone])$



Use the Field Calculator to generate unadjusted travel time values for the MINUTES\_R field.

3. Next use the Field Calculator to determine the absolute slope and place that value in the SLOPE\_ABS field. Remove the previous formula from the text field. Choose the Abs function from the list of functions and select the SLOPE1 field. Abs ([Slope1]) should display in the text field. Click OK.
4. Move the table if necessary to look at the changes these calculations have made to the thematic display of the Streets -

Slope layer. Keep the Streets - Slope table open and save the map document.

## Calculating Slope Adjustment

1. In the Streets - Slope table, calculate slope adjustment factor by right-clicking on the Slope\_Adj1 field header, choosing Field Calculator, and removing the previous formula from the text field. Input the following equation and click OK.

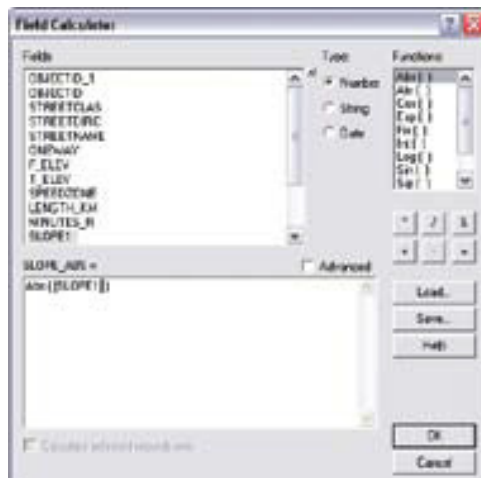
$$1 + ([Slope1]/10)^2$$

Slope\_Adj1 is a multiplication factor that increases travel time for steep slopes. Table 1 shows the empirical slope factors in 1 percent intervals. Notice that it takes twice as long to climb

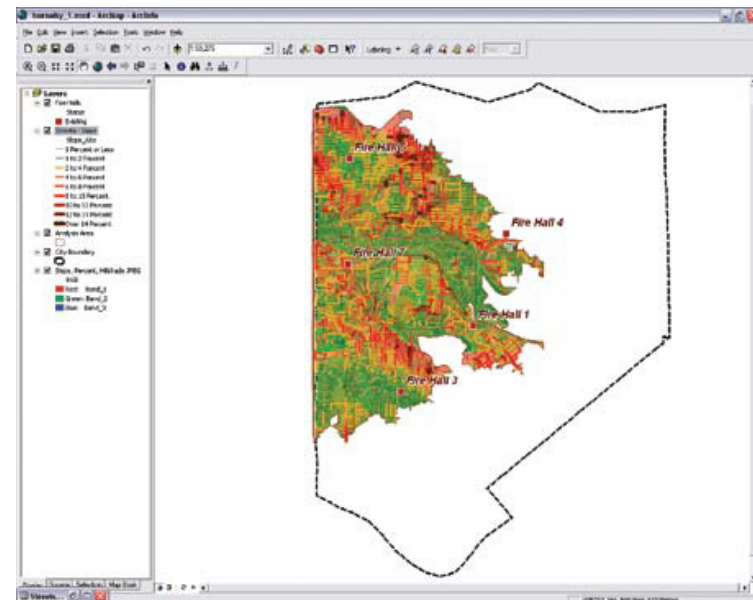
or descend a 10 percent slope than it does to travel on flat street segments.

2. Now, calculate the slope-adjusted travel time in minutes. Right-click on the MINUTES\_S field header, choose Field Calculator, remove the previous formula from the text field, and input the following formula:

$$[Minutes_R] * [Slope_Adj1]$$



Use the absolute value function on SLOPE1 to obtain absolute slope values.



Note the effects the field calculations have made on the symbolization of the Streets – Slope layer.



Table 1: Slope adjustment factors.

Slope (in percent)	Travel Time Multiplier	Comments
0	1.00	Base time
1	1.01	
2	1.04	
3	1.09	
4	1.16	
5	1.25	1.25 times as long
6	1.36	
7	1.49	
8	1.64	
9	1.81	
10	2.00	Twice as long
11	2.21	
12	2.44	
13	2.69	
14	2.96	
15	3.25	
16	3.56	
17	3.89	
18	4.24	
19	4.61	
20	5.00	5 times as long
21	5.41	
22	5.84	
23	6.29	
24	6.76	
25	7.25	
26	7.76	
27	8.29	
28	8.84	
29	9.41	
30	10.00	10 times as long
35	13.25	
40	17.00	Very steep

- Calculate slope adjusted travel speed in minutes. This calculation incorporates the slope adjustments in Table 1 and generates the equivalent speed for travel on each street segment. Right-click on the [Speed\_Adj1] field header, choose Field Calculator, remove the previous formula from the text field, and input the following equation:

$$([\text{Length\_Km}]/[\text{Minutes\_S}])*60$$

- Save the map document.

### Building the Street Network Dataset

Close ArcMap and open ArcCatalog. In the Burnaby\_Fire geodatabase, navigate to the Transport\_Model feature dataset and refresh ArcCatalog. Select the Highways\_Streets feature geodatabase class, click on the Preview tab, and choose Table from the drop-down. Look at the ONE\_WAY, F\_ELEV, and T\_ELEV fields.

- In ArcCatalog, choose Tools > Extensions and check the box next to Network Analyst.
- Right-click on Transport\_Model, choose New > Network Dataset, name the new dataset Transport\_Model\_ND, and click Next.
- Check the box next to the Highways\_Streets feature class and click Next.

4. Click the Connectivity button and note that End Point connectivity is checked. Click Next.
5. Click to modify connectivity with the elevation fields F\_ELEV and T\_ELEV. Click Next.
6. Accept Global Turns and click Next.

## Defining Network Attributes and Turn Rules

Network attributes for time and distance travel must now be specified.

1. Click the Add button. In the wizard pane to specify the attributes for the network dataset, add the Length\_KM, Minutes\_R, and Minutes\_S fields and set the values as shown in Table 2.

Table 2: Values for new network dataset.

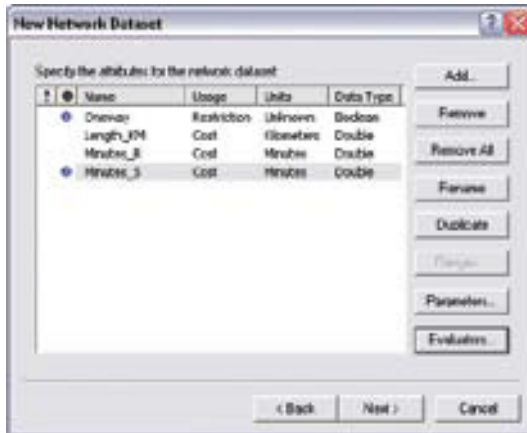
Name	Usage Type	Units	Data Type	Set as Default
Length_KM	Cost	Kilometers	Double	No
Minutes_R	Cost	Minutes	Double	No
Minutes_S	Cost	Minutes	Double	No

2. If Oneway is not already set as a default, right-click on it and set it as a default.
3. In the same wizard pane, highlight Minutes\_S and click the Evaluators button.

4. Click the Default Values tab. Right-click the element named Turn, choose Type, and click VBScript.
5. With the Turn element still highlighted, look for the Evaluator Properties button on the right side of the wizard pane. Click on it.
6. In the Script Evaluators dialog box, make sure Turn is set as type, and click the Load button. Navigate to the \Burnaby\Utility folder. Locate and load TurnTime.sev. Click OK.
7. Back in the previous dialog box, select Minutes\_R from the Attribute drop-down box. Right-click the element named Turn, choose Type, then click VBScript.
8. With the Turn element still highlighted, look for the Evaluator Properties button on the right side of the wizard pane. Click on it.
9. In the Script Evaluators dialog box, make sure Turn is set as type and click the Load button. Navigate to the \Burnaby\Utility folder. Locate and load TurnTime.sev. Click OK. Click Apply. Click OK.
10. Back in the New Network Dataset wizard pane, click Next.

These 10 steps have established the turn rules for the streets corrected for slope and streets not corrected for slope. The default turn rules in TurnTime.sev specify a 10-second delay for left turns, a 5-second delay for right turns, and a 2-second delay

Defining Attributes and Turn Rules



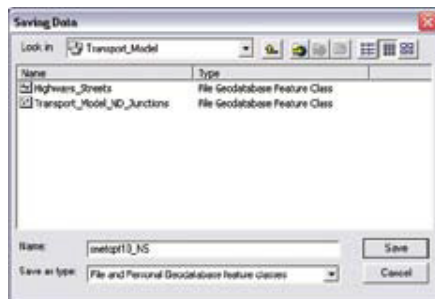
In ArcCatalog, set the network attributes for time and distance travel using the New Network Dataset wizard.



Under the default values for the Turn element for the MINUTES\_S Evaluator, attach a VBScript.



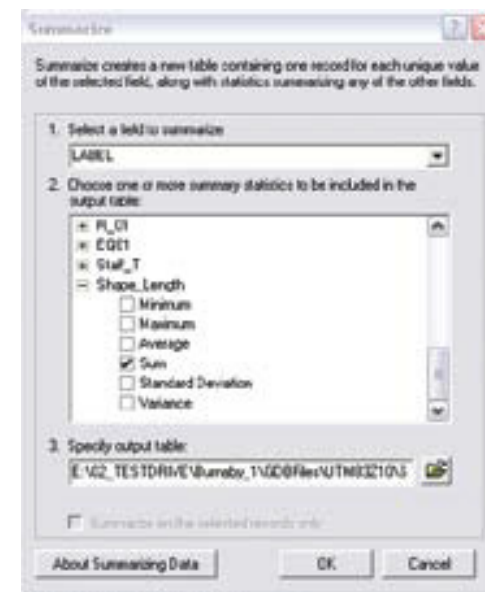
Apply TurnTime.sev to the Evaluator for MINUTES\_S.



After joining the fire hall attributes to the network analysis layers, save these layers as feature classes so they are permanent and can be shared. Store these feature classes in the Transportation Model in the Burnaby geodatabase.



Use an expression to label the service areas with the area of each in square kilometers.



In the Optimized Travel Network, Slope attribute table, summarize on the LABEL field using the Shape\_Length statistics.

for straight travel from one segment to the next. A 30-second penalty is imposed on U-turns. Table 3 lists the turn rules applied for municipal areas.

Table 3: Turn rule options.

Turn Rule	Right-Turn Penalty (in seconds)	Left-Turn Penalty (in seconds)	U-Turn Penalty (in seconds)	Straight Line Travel Penalty(in seconds)
No Penalty	0	0	0	0
Slight Penalty	1	2	10	0
Moderate Penalty	2	4	20	0.5
High Penalty	3	5	30	1
Very High Penalty	5	10	30	2
Turn Angle, Minimum	30	210	150	330
Turn Angle, Maximum	150	330	210	30
Turn Angle, Range	120	120	60	60

11. In the next wizard pane, click Yes to establish driving directions.
12. Review the summary page for the New Network Dataset, select the text, copy it to the Windows clipboard, and paste it into a WordPad document. Save it as NW\_YYMMDD.rtf (i.e., year, month, day) in the \Utility folder.

13. Click Finish and click Yes to build dataset. Wait while the network dataset builds.

## Adding the Network Dataset

The next steps add the network dataset to the map document so travel can be modeled.

1. Close ArcCatalog and restart ArcMap and open Burnaby1.mxd.
2. Add Transport\_Model\_ND from the Transport\_Model feature dataset in the GDBFiles folder. Do not add other participating feature classes. Move the network dataset below Highways, Streets and turn it off.
3. Right-click on the Streets - Slope layer and choose Zoom to Layer.
4. Enable the Network Analyst extension. Choose Tools > Extensions and check Network Analyst. Add the Network Analyst toolbar and dock it at the top of the map.
5. Make the Network Analyst Window visible by clicking the Show/Hide Network Analyst Window button on the Network Analyst toolbar.

## Setting Up Service Areas

The steps in this section create the service areas and load fire hall locations.

1. On the Network Analyst toolbar, click the Network Analyst drop-down and select New Service Area. Click the Properties button on the top of the Network Analyst Window and name this service area Optimized Travel NW, Slope.
2. Repeat this process to build a second service area called Optimized Travel NW, No Slope.
3. Create a new layer group, name it Optimized Travel NW Group, and drag and drop both service areas to add them to the group. Move Optimized Travel NW Group to the bottom of the TOC, above Slope, Percent, Hillshade JPEG.

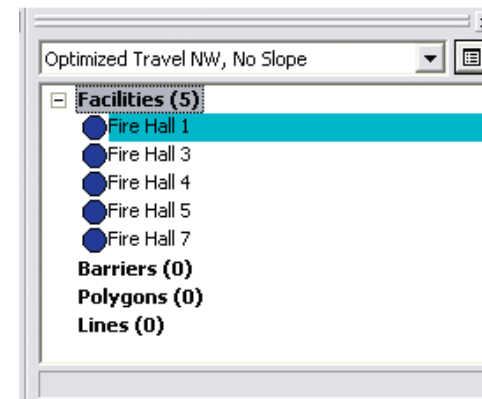
## Loading Fire Hall Locations into the Network

The following steps will be applied to both the no slope and slope network datasets to load the fire hall locations.

1. Change the network dataset in the Network Analyst Window drop-down to Optimized Travel NW, No Slope. Right-click on Facilities (0) and choose Load Locations. In the Load Locations dialog box, add the parameters shown in Table 4. Click OK. Facilities now shows (5) items. Expand the entry to see that fire halls 1, 3, 4, 5, and 7 have loaded.



Load the fire hall locations into the network and set the sort field as INDEX and the search tolerance at 200 meters.



Once the fire hall locations have been loaded, check that halls 1, 3, 4, 5, and 7 are listed in the Network Analyst window.



2. Change the Network Analyst Window drop-down to Optimized Travel NW, Slope. Using the same procedure and parameters, load fire hall locations into this dataset.
3. Save the map document.

Table 4: Fire hall location parameters.

Field	Value
Load From	Fire Halls
Sort Field	Index
Name	LABEL
Search Tolerance	200 Meters

## Defining Travel Area Parameters for No Slope and Slope

1. Right-click on the Optimized Travel NW, No Slope layer in the TOC and choose Properties.
2. Click on each tab listed in Table 5 and change the settings as indicated. On the Analysis Settings tab, make sure the Impedance is set to Minutes\_S (Minutes). This is an important parameter and it is not a default. Double-check these parameters and click Apply and OK.
3. Save the project.
4. Repeat these analysis selections for Optimized Travel NW, Slope service area.
5. Save the map document.

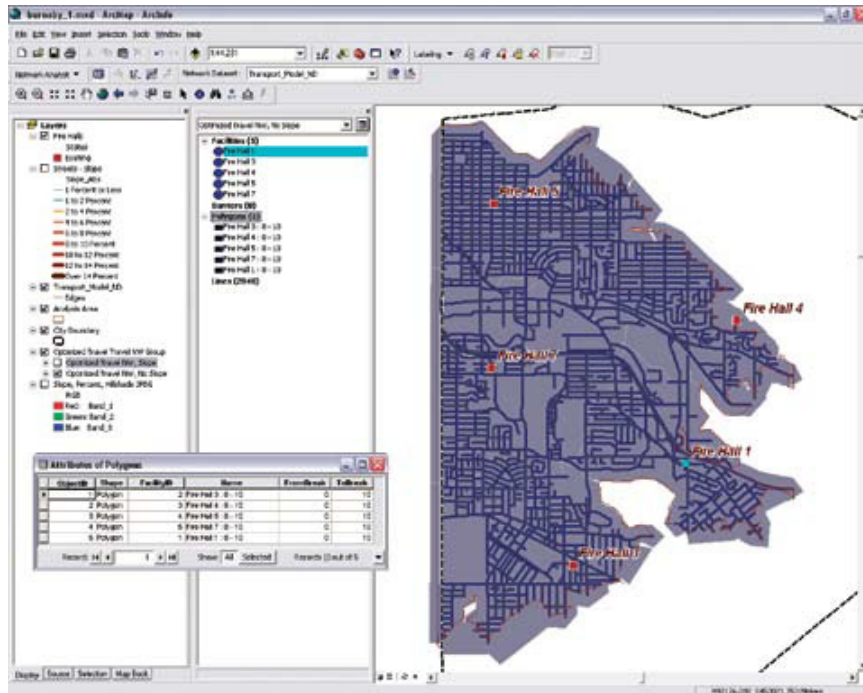
Table 5: Travel area parameters.

Tab and Parameters	Setting
Analysis Settings Tab	
Impedance	Important: Use Minutes_S (Minutes) for Slope. Use Minutes_R (Minutes) for No Slope.
Default Breaks	10
Oneway	Check Restrictions
Polygon Generation Tab	
Generate Polygons	Check
Detailed	Select
Trim Polygons	Check and Set Trim to 200 Meters
Multiple Facilities Options	Not Overlapping
Overlap Type	Disks (Not essential but a good habit)
Line Generation Tab	
Generate Lines	Check
Include Network Source Fields	Check
Overlap Options	Not Overlapping
Accumulation Tab	
Minutes_S, Minutes_R, Length_Km	Check

## Solving

With all the parameters established for the network datasets, the network solver can be applied.

1. With the Optimized Travel NW, No Slope selected in the Network Analyst Window drop-down, click the Solve button on the Network Analyst toolbar. When the process is complete, five polygons will be added to the Network Analyst Window. Save the map document.



After setting the travel area properties, click the Solve button to generate the service area polygons.

2. Change the drop-down to Optimized Travel NW, Slope and use the same process as in the previous step. Save the document again.
3. Turn off the Streets - Slope and Slope, Percent, Hillshade JPEG layers and turn the Optimized Travel NW, Slope and Optimized Travel NW, No Slope layers on. Inspect both network solutions to discern the differences between them.
4. Save the map document.

## Joining Attribute Tables

Right-click on Polygons in the Network Analyst Window for either service area and open the attribute table. Notice the table contains a NAME field that lists the responding station and the 10-minute maximum time. Open and inspect the Line attributes table for one of the service areas. Lines contain only a Facility ID for the related fire hall but no fire hall name. These network output file attribute tables will require tabular joins back to the Fire Halls layer attribute table.

1. Join the Fire Halls table with the polygon and line attribute tables to incorporate this data. Right-click on Polygons in the Optimized Travel NW, Slope layer in the TOC and choose Joins > Joins and Relates. Fill in values for the Join Data dialog box using the parameters in Table 5. Click OK.
2. Repeat this process for the lines in Optimized Travel NW, Slope and for polygons and lines in Optimized Travel NW, No Slope. It is clear now why the Fire Halls were indexed. Open the attribute tables to ensure the joins were made correctly. If not, right-click on the layer and choose Joins and Relates > Remove Joins.
3. Save the project.

Table 6: Join parameters.

Join Parameter	Value
Field in this layer that the join will be based on	FacilityID
Table to join to this layer	Fire Halls
Field in the table to base the join on	INDEX

## Exporting Travel Areas and Travel Networks to New Feature Classes

The results of a service area solver are stored in the ArcMap document. To share these results with others, network solutions can be saved as geodatabase feature classes or shapefiles.

1. Make sure ArcCatalog is closed. In the ArcMap TOC, right-click on Lines in the Optimized Travel NW, No Slope layer and choose Data > Export Data.
2. Export All features using the layer's coordinate system. Click the folder icon button to browse to Burnaby\_Fire.gdb \Transport\_Model. Set Save as type to Personal and File Geodatabase feature classes. Name the file snetopt10\_NS. Add the feature class to the map document.
3. Save the map document.

Table 7: Names for exported feature classes.

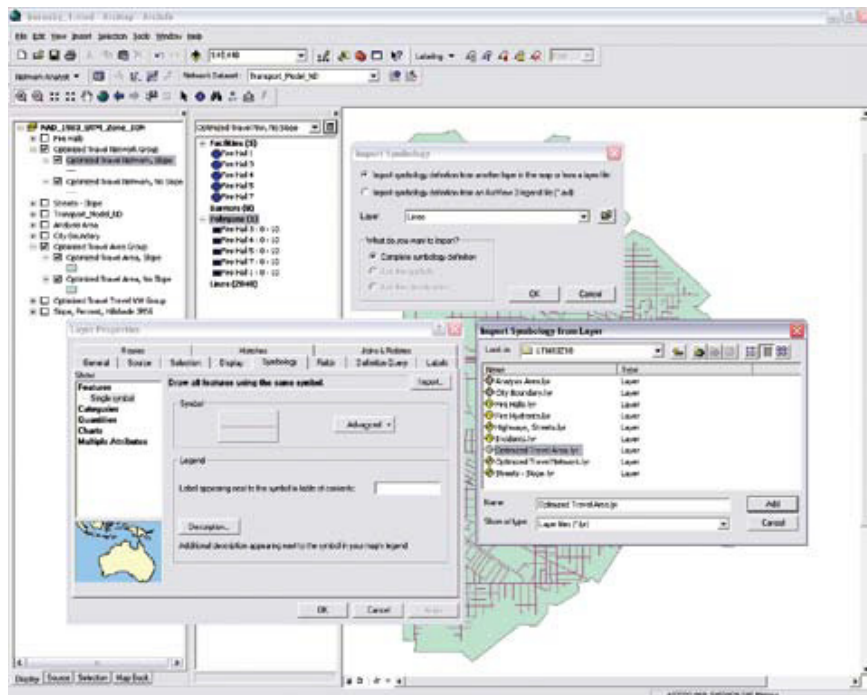
Network Analysis Layer	Feature Class Name
Optimized Travel NW, No Slope, Lines	snetopt10_NS
Optimized Travel NW, No Slope, Polygons	sareaopt10_NS
Optimized Travel NW, Slope, Lines	snetopt10_SL
Optimized Travel NW, Slope, Polygons	sareaopt10_SL

## Organizing and Symbolizing Travel Areas and Networks

After creating feature classes for the networks and areas, grouping and symbolizing them will make comparing them easier.

1. Minimize all layers and groups in the TOC. Create a new group and name it Optimized Travel Network Group. Place this group below Fire Halls.
2. Rename snetopt10\_SL to Optimized Travel Network, Slope and drag it to the Optimized Travel Network Group.
3. Rename snetopt10\_NS to Optimized Travel Network, No Slope and drag it to the Optimized Travel Network Group.
4. Create another new group, call it Optimized Travel Area Group, and place this group above the Travel NW Group.
5. Rename sareaopt10\_SL to Optimized Travel Area, Slope and place it in the Optimized Travel Area Group.
6. Rename sareaopt10\_NS to Optimized Travel Area, No Slope and place it in the Optimized Travel Area Group.

7. Double-click on the Optimized Travel Area, Slope layer. Click the Symbology tab and click the Import button. Navigate to Optimized Travel Area.lyr in E:\02\_TESTDRIVE\Burnaby\_1\GDBFiles\ UTM83Z10 to import its thematic symbology. Repeat this process for Optimized Travel Area, No Slope.
8. Use the same procedure to import the Optimized Travel Network.lyr symbology for Optimized Travel Network, Slope and Optimized Travel Network, No Slope.



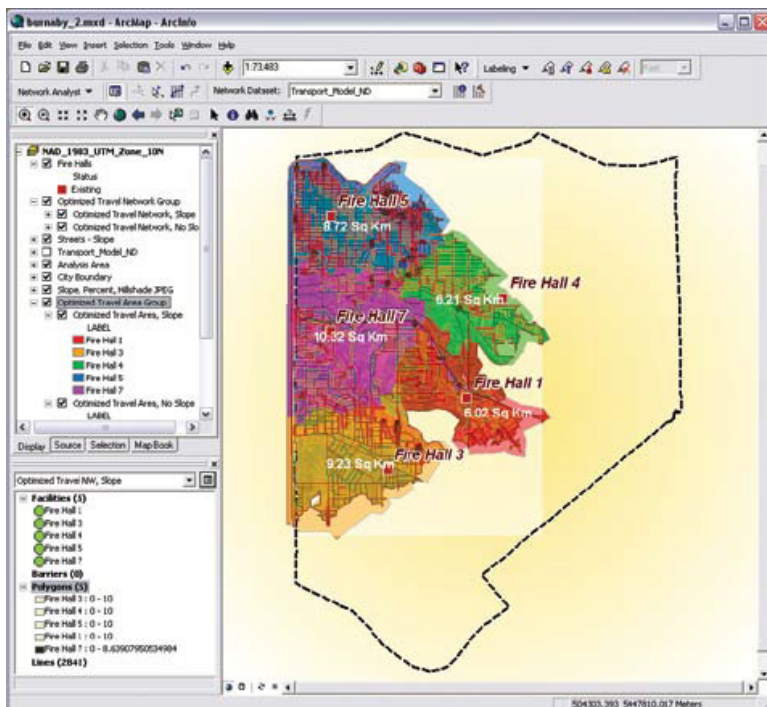
After generating the service areas and networks, use the layer files in the sample dataset to quickly symbolize these layers.

## Calculating Optimized Area for Each Fire Hall

Now summarize the characteristics of the optimized travel areas.

1. Open the attribute table for Optimized Travel Area, Slope and notice that each fire station has only one footprint polygon. The area is calculated in square meters. To label each polygon with the area in square kilometers requires only applying a simple math function and rounding.
2. Right-click on the Optimized Travel Area, Slope layer name in the TOC and click Label Features. Right-click on this layer again and select Properties. Click on the Label tab. Change the text symbol color to white, bold, and 12 points. Do not close this dialog box.
3. Click the Expression button. Type `ROUND([Shape_Area]/1000000,2) &" Sq Km"` into the formula window. Click the Verify button to check the calculation and see a sample label. Click OK.

- Looking at the service areas, new Fire Hall 7 has the largest area (10.32 sq km) and Fire Hall 4 has the smallest (6.21 sq km). To effectively model response areas for all Burnaby fire halls would require building a complete three-dimensional street network and adding the other stations located outside of the study area.



When complete, the map allows the service areas and fire hall locations to be easily compared visually.

## Calculating Total Street Length Traversed by Each Fire Hall

Open the Optimized Travel Network, Slope attribute table. Note that each fire hall has multiple street segments. The Label field identifies which segments correspond with each station. The next step will be to summarize this data to assign total kilometers to each station.

- Open the attribute table for Optimized Travel Network, Slope.
- Right-click on the Label field and choose Summarize.
- Summarize on LABEL. Under statistic to summarize on, scroll to the bottom of the list, expand Shape \_Length, and check Sum.
- Name the table snetopt10\_SL\_Sum1, specify that it is a File and Personal Database Table, and store it inside Burnaby\_Fire.gdb.
- Add the summary table into the map and open it. Notice that Fire Hall 5 protects nearly 98 km of streets while Fire Hall 4 protects only a little more than 50 km. (Note that the dataset was clipped for training purposes.) The new Fire Hall 7 protects nearly 84 km of streets including a significant portion of Highway 1.



## Conclusion

In this exercise, slope- and turn-adjusted time-based optimum response areas were used for carefully defining primary response areas for each fire hall and its neighboring stations. Modeling coverage for existing and proposed stations often requires running multiple models and summarizing value, hazard, risk, and protection within all station footprints for multiple scenarios. This requires a bit of work, but the results are very convincing.

## Acknowledgments

The author thanks the City of Burnaby Fire Department, the Burnaby Engineering Department, and Esri Canada Limited for the opportunity to define and test this complex time-based solution and for the opportunity to use it in a training mode.

(This [article](#) originally appeared in the Spring 2008 issue of *ArcUser*.)

# Coding and Counting

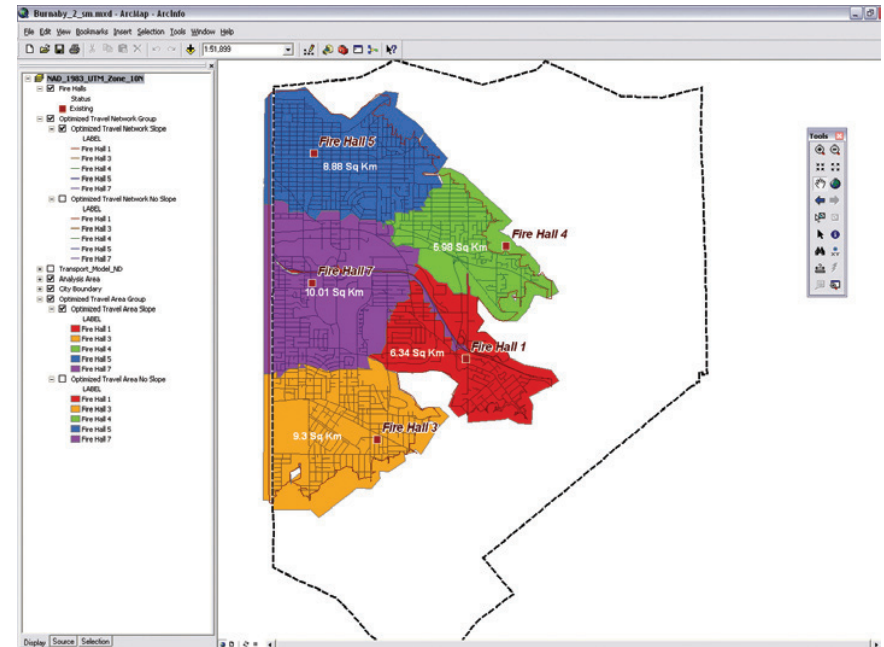
Joining and summarizing tables to add information

By Mike Price, Entrada/San Juan, Inc.

In the last issue of *ArcUser*, the tutorial [“Slopes, Sharp Turns, and Speed—Refining emergency response networks to accommodate steep slopes and turn rules”](#) showed how to model emergency service area coverage for existing and proposed stations using the ArcGIS Network Analyst extension.

In the previous exercise, a network dataset was created, its attributes and turn rules defined, and optimized service areas for fire halls were generated. Travel values, with and without slope adjustments, were calculated, and the optimized area and total street length for each fire hall were calculated. The exercise in this issue's tutorial builds on that project with an additional exercise showing how to map and count the hydrants and incidents in the optimized service areas that were previously generated.

The data for both exercises was supplied by the city of Burnaby, British Columbia, Canada. Burnaby, the third largest urban center in the province, is a major business, residential, and transportation corridor between Vancouver and British Columbia's Lower Mainland. Elevation ranges from mean sea level to 375 meters. Land features have controlled and constrained development throughout this community.



This tutorial uses a stepped-down version of the map document created in the previous tutorial. The optimized travel areas in this tutorial will be spatially joined with hydrant and incident data and summarized by service area.

The Burnaby Fire Department serves the entire municipal area and provides aid response into neighboring jurisdictions. The department staffs six fire halls, and a new station will open soon. The agency's staff numbers 286 and, in 2006, responded to

13,400 calls. The Burnaby Fire Department works closely with the city's Engineering Department to plan and optimize service throughout the area. Burnaby's Engineering Department uses ArcGIS Network Analyst to optimize response areas.

### What You Will Need

- ArcGIS Desktop 9.3 (ArcInfo, ArcEditor, or ArcView license level)
- [Sample data from ArcUser Online](#)

## Getting Started

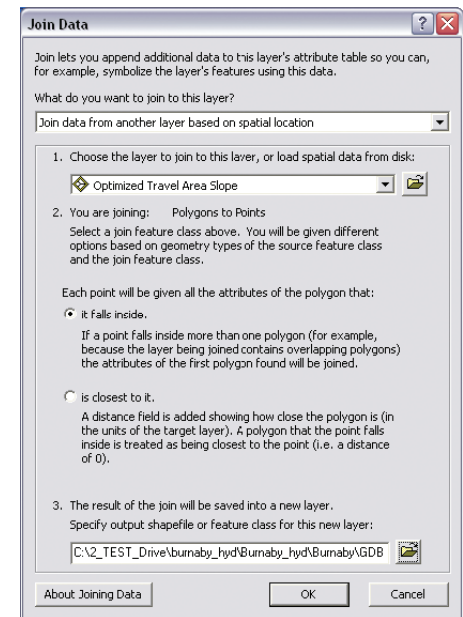
Download the zipped sample dataset for this exercise from *ArcUser Online* ([esri.com/arcuser](http://esri.com/arcuser)) and place it near the root of the drive that will contain the project. Unzip the data and explore it in ArcGIS ArcCatalog.

The archive should generate a directory structure that includes folders for geodatabase files (GDBFiles) and a utility folder containing Microsoft Excel spreadsheets that explain calculations that were incorporated in the previous exercise as well as a VBScript that assigns various penalties for different types of turns. The sample dataset also contains burnaby\_2\_sm.mxd, the ArcMap document that will be used in the exercise.

## Adding Information Using Spatial Joins

This exercise explains how to map and code Burnaby's fire hydrants to specify the closest optimized fire hall and count the hydrants in the station's optimized response area.

1. Start ArcMap and open burnaby\_2\_sm.mxd.
2. Load Fire Hydrants Layer file from the Burnaby\_Fire.gdb in the GDBFiles > UTM83Z10 folder.
3. In the table of contents (TOC), right-click on Fire Hydrants and choose Joins and Relates > Join. In the Join Data dialog box, select Join data from another layer based on spatial location from the first drop-down. Click the second drop-down and choose Optimized Travel Area Slope.
4. The dialog box should indicate this will join polygons to points. Click the radio button next to It falls inside.



Use a spatial join to combine hydrant point data with service area polygons.

- Click the Browse button. In the Save Data dialog box, change the Save as Type to File and Personal Geodatabase feature classes. Navigate to and save this new feature class in Burnaby\_Fire.gdb as Fire\_Hydrants\_Halls. Click Save and click OK.
- Right-click on the new Fire\_Hydrants\_Halls feature class and inspect its attribute table to verify that join was performed.
- Remove Fire\_Hydrants\_Halls from the TOC. Right-click on Fire Hydrants in the TOC and choose Properties > Source and set the data source to Fire\_Hydrants\_Halls. Save the map document.

## Counting Hydrants with Summarize

Summarizing on a field in a table can easily generate useful information about data. In this case, Summarize will be used to count the hydrants in each fire hall's travel area.

- Open the Fire Hydrants attribute table and locate the Label field. Right-click on this field and select Summarize. To get only a count, don't specify any summary statistics. Save as a File Geodatabase table called Hydrants\_Join\_Sum1 and store it in the Burnaby\_Fire.gdb.
- Add the table to the map and check it. Based on the clipped street set, which Fire Hall is responsible for testing the most

hydrants? (The answer is the new Fire Hall 7, which has 491 hydrants.)

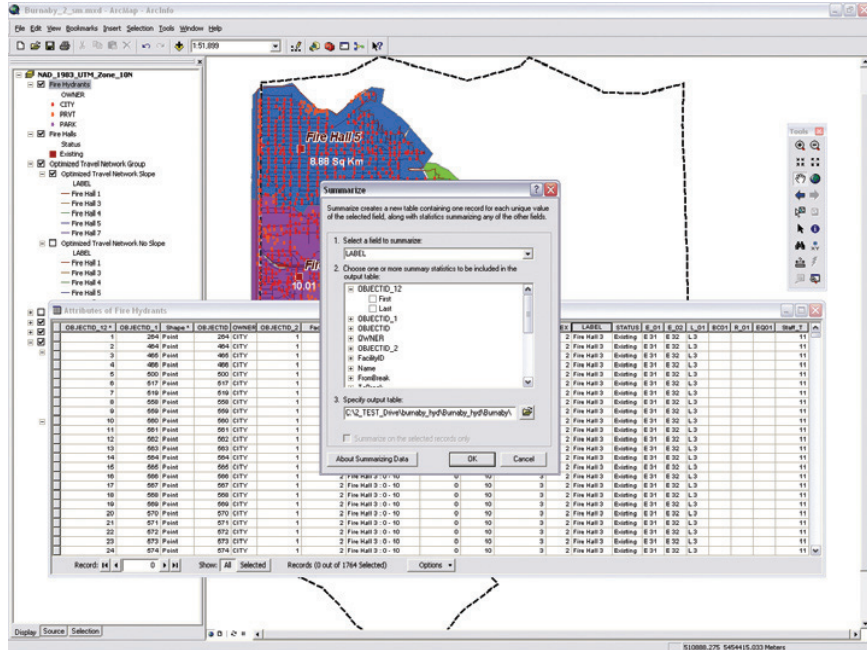
## Updating Labels

The number of hydrants in each service area can be associated with the rest of the service area record by joining the summary table with the Optimized Travel Area Slope attribute table. Label each service area with the fire hall number and the number of hydrants it contains by joining the hydrant summary table using a simple VBScript.

- In the TOC, right-click on Optimized Travel Area Slope and select Joins and Relates > Joins.
- In the Join dialog box, choose Join Attributes from a Table. Set LABEL as the field to join. Choose Hydrants\_Join\_Sum1 as the table to join to and choose LABEL field as the field in Hydrants\_Join\_Sum1 to base the join on. Choose Keep All Records and click OK. Accept indexing.
- Open and inspect the Optimized Travel Area Slope table. Does each fire hall record now contain hydrant counts as attributes from Hydrants\_Join\_Sum1?

OBJECTID_12 *	LABEL	Crit_LABEL
1		0
2	Fire Hall 1	215
3	Fire Hall 3	390
4	Fire Hall 4	221
5	Fire Hall 5	439
6	Fire Hall 7	496

The resultant summary table reveals how many hydrants are maintained by each hall.



After creating a new feature class from the spatially joined data, summarize hydrants on LABEL field.

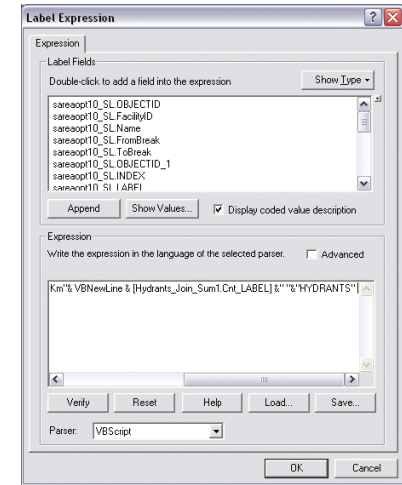
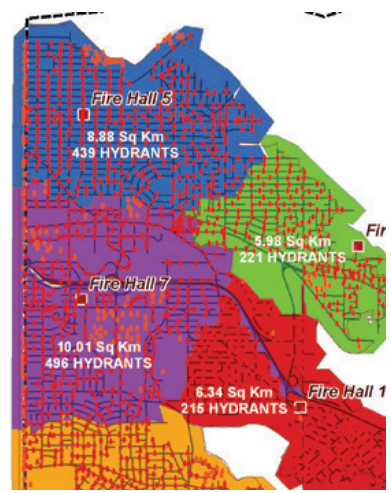
- A label expression has already been applied to label each service area with its area in square kilometers.

`Round( [sareaopt10_SL.Shape_Area] /1000000,2)&" Sq Km"`

Now add some additional script to include the number of hydrants in the label. Double-click on Optimized Travel Area Slope to open the Properties dialog box and select Labels > Expression. Add the following line to the end of the existing expression and click OK.

`& vbCrLf & [Hydrants_Join_1.Cnt_LABEL] &" "&"HYDRANTS"`

- Save the map document.



Add to the existing labeling expression to include the number of hydrants in each label.

### Posting Emergency and Nonemergency Calls

In the United States, the National Fire Incident Reporting System (NFIRS) uses a three-digit numeric code to distinguish between emergency and nonemergency calls. Although the exercise data comes from Canada, NFIRS codes have been added to create a meaningful thematic legend and build summary statistics.

- Turn off the Fire Hydrants layer. Load Incidents.lyr from GDBFiles > UTM83Z10 and inspect its symbology. These points represent responses by the Burnaby Fire Department to incidents that happened in 2007. This layer applies a

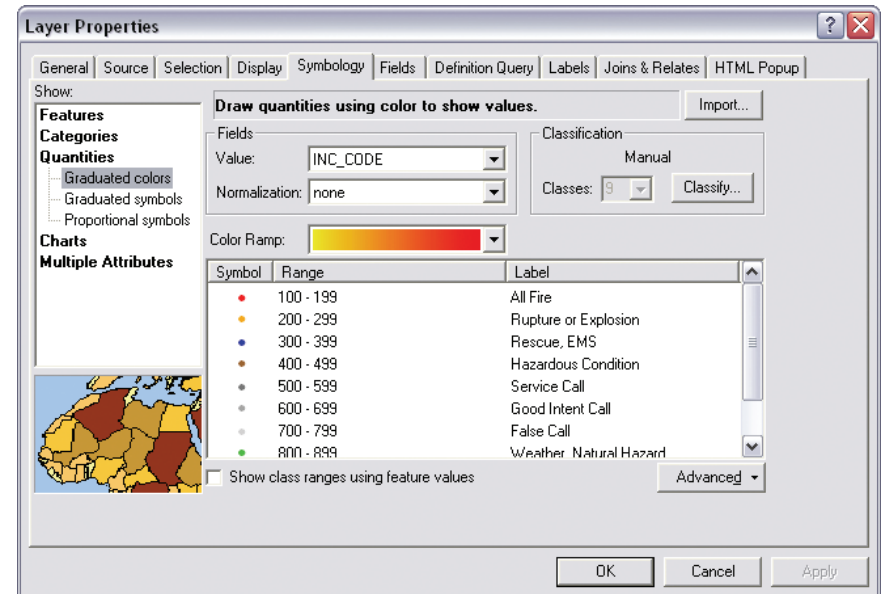


Quantities—Graduated Colors legend to display emergency and nonemergency calls by code value range. Table 1 lists the numeric ranges defined by NFIRS 5.0. These ranges will be used to build subsets of the 2007 calls. For a complete list of the NFIRS 5.0 codes and descriptions, download the NFIRS Reference Guide from [www.nfirs.fema.gov/\\_download/NFIRS50CRG\\_011608.pdf](http://www.nfirs.fema.gov/_download/NFIRS50CRG_011608.pdf). Chapter 3 contains detailed descriptions.

Table 1: NFIRS 5.0.

Inc_Code Range	Description
100–199	All Fire
200–299	Rupture or Explosion
300–399	Rescue, EMS
400–499	Hazardous Condition
500–599	Service Call
600–699	Good Intent Call
700–799	False Call
800–899	Weather, Natural Hazard
900–999	Other or Special Incident

- To separate the calls by type (fire, rescue and EMS, and other calls), make three copies of the master incident set and use three definition queries to separate the data. In the TOC, right-click on the Incidents Layer file and copy it. Right-click on the Data Frame name and paste three copies of the Incidents.lyr. Rename the top copy to Fire, Explosion, Hazmat. Name the second copy Rescue, EMS. Name the third copy Other Calls. Turn off the Incidents Layer file and the copies.



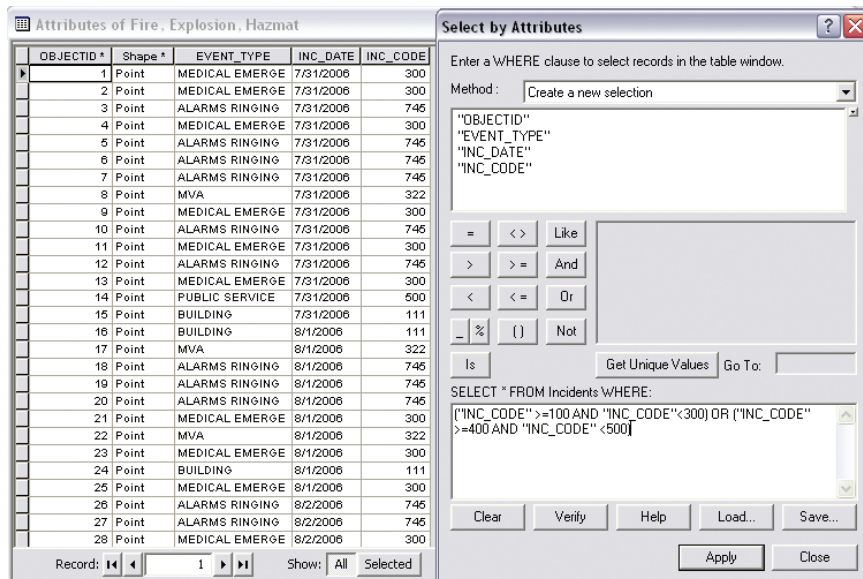
The Incidents Layer file symbolizes the NFIRS codes for Burnaby incidents in 2007. Make three copies of the Incidents Layer for the three categories of incidents.

- Open the attribute table for Fire, Explosion, Hazmat. Click the Options button on the table frame and choose Select by Attributes. Create a new selection by typing the definition query  
`("INC_CODE" >=100 AND "INC_CODE"<300) OR ("INC_CODE" >=400 AND "INC_CODE" <500)`  
 (shown in Table 2) in the text box and click Apply.

Table 2: Definition queries.

Layer	Definition Query
Fire, Explosion, Hazmat	("INC_CODE" >=100 AND "INC_CODE"<300) OR ("INC_CODE" >=400 AND "INC_CODE" <500)
Rescue, EMS	"INC_CODE" >=300 AND "INC_CODE"<400
Other Calls	"INC_CODE" >=500

4. Open the attribute table and sort on the INC\_CODE field to verify that the definition query selected the correct records.



Use definition queries to select incidents by NFIRS codes for each incident category, save the selected records for each category as a new feature class, and use the new feature classes as the data source for the incident layers.

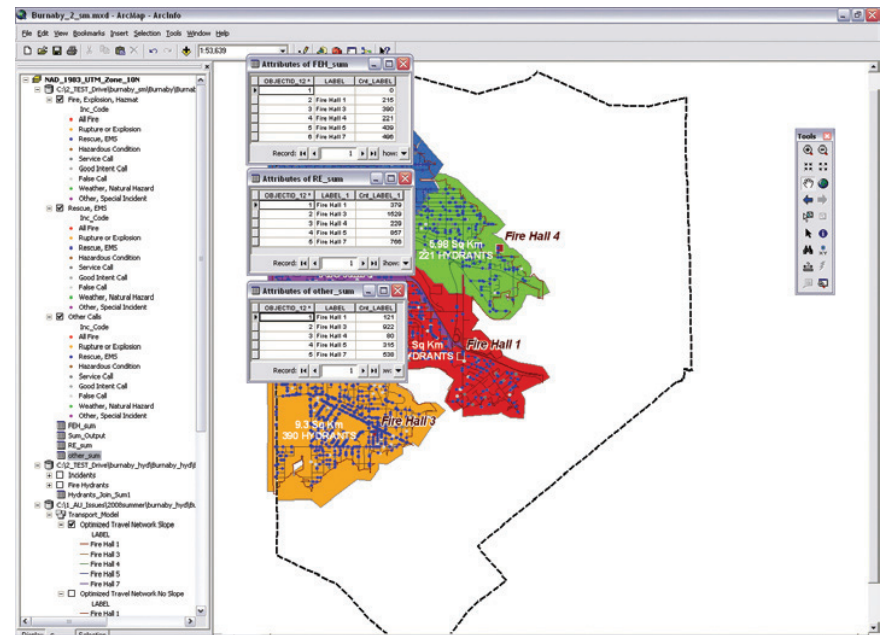
- Right-click on Fire, Explosion, Hazmat and choose Data > Export. Save the selected features as a feature class called FEH in the Burnaby\_Fire.gdb. Do not add this layer to the map.
- Open the Properties dialog box for Fire, Explosion, Hazmat and change the data source to the FEH feature class.
- Use the same procedure and the definition queries in Table 2 to select records from the Rescue, EMS and Other Calls layers. Name the output feature classes RE and Other, respectively. Save the map document.

## Joining and Summarizing Service Call Data

Counting the incidents for each fire hall's optimized response area requires spatially joining the service areas to the incidents, then summarizing on the calls.

- Right-click on Fire, Explosion, Hazmat in the TOC and choose Joins and Relates > Join.
- In the Join dialog box, select Join data from another layer based on spatial location. Set the layer to join as Optimized Travel Area Slope. Change Save as Type to File and Personal Geodatabase feature classes. Save the new feature class inside Burnaby\_Fire.gdb as Fire\_Explosion\_HazMat\_Halls. Click OK. Remove this layer from the map document.

- Double-click on the Fire, Explosion, Hazmat layer in the TOC and change the data source to Fire\_Explosion\_Hazmat\_Halls, the new geodatabase feature class.
- Repeat this process two more times. Create the Rescue\_EMS\_Halls feature class by spatially joining the Rescue, EMS points to Optimized Travel Area Slope polygons. Create the Other\_Calls\_Halls by spatially joining Other Calls points with Optimized Travel Area Slope polygons. Remove these new layers from the map document and save the map document.
- Summarize the incident for the selected sets in each layer using the same method employed previously with the hydrants data. Right-click on the Label field and choose Summarize. To get only the count, do not check any boxes in the Summarize dialog box. Save the output tables in the Burnaby\_Fire.gdb as File and Personal Geodatabase tables named FEH\_sum, RE\_sum, and Other\_sum, respectively. Add each table to the map and save the map document.



Summarize the incidents for each layer on the LABEL field to learn how many incidents of each type were handled by each fire hall.

- Load each summary table into the map document.

Which fire hall had the most rescues and EMS calls? Which fire hall had the fewest? With two engines, a ladder, and 11 personnel, Fire Hall 3 has the most resources, but it also performs the most rescues.

## Conclusion

This elaborate analysis assessed and validated public safety response capabilities for a major Canadian provider of fire and EMS services. The processes and workflow taught in this exercise are similar to those used by public safety analysts. ArcGIS 9.3 facilitates and helps standardize this analytical process.

## Acknowledgments

The author thanks the City of Burnaby Fire Department, the Burnaby Engineering Department, and Esri Canada for the opportunity to define and test this complex time-based solution and use this data as a training set.

(This [article](#) originally appeared in the Summer 2008 issue of *ArcUser*.)

# Using 9.3 Functionality and Scripts

Calculating transportation network slope and travel parameters

By Mike Price, Entrada/San Juan, Inc.

Recent tutorials in *ArcUser* modeled time-based travel on steeply sloping streets in Burnaby, British Columbia. This exercise shows how new geometry calculation features in ArcGIS Desktop 9.3 can be used for generating average slope values on short street segments from starting point to endpoint.

This calculation was used in "[Slopes, Sharp Turns, and Speed—Refining emergency response networks to accommodate steep slopes and turn rules](#)" in the Summer 2008 issue of *ArcUser* to adjust travel time on steep Burnaby hills. Slope values were provided as part of the exercise and were determined using third-party software and outside data management in an Excel spreadsheet.

However, with the Calculate Geometry function in ArcGIS 9.3, the x and y coordinates can be calculated for segment endpoints. These endpoints may be converted to two 3D point files and their elevation determined. Using the x, y, and z coordinates of endpoints and the segment length, approximate slope can be generated by dividing the change in elevation by the segment length—a simple ratio of rise over run. This procedure requires the ArcGIS 3D Analyst extension to create three-dimensional

street segments. The rest of the calculations are handled using core functionality in ArcGIS Desktop 9.3.



This exercise uses a small portion of the data used in previous tutorials that modeled the service areas of the Burnaby Fire Department.

A file supplied in the sample dataset for this exercise, Slope\_Time\_Formulas.rtf, contains all necessary formulas for this exercise. These formulas can be copied and pasted to eliminate typing and possible typos; just be careful with field selection and do not change field names without editing the appropriate scripts.

### What You Will Need

- ArcGIS Desktop 9.3 (ArcView, ArcEditor, or ArcInfo license level)
- ArcGIS 3D Analyst extension
- [Sample data from ArcUser Online](#)

## Getting Started

Download the [sample dataset](#) and unzip it in a folder. The training dataset is contained in a folder named Burnaby2 and includes a file geodatabase containing a feature dataset named Transportation\_Model. Inside this dataset is a single feature class named Streets\_Slope\_Calc.

Open the table for this feature class in ArcCatalog and inspect the data fields. This dataset is a three-dimensional representation of the northwest part of the Burnaby streets used in a previous

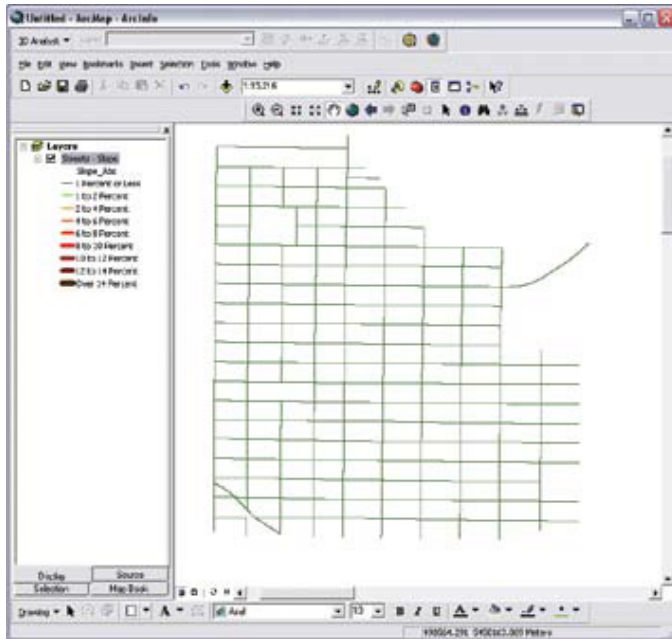
exercise but has six additional columns that will be used to store x, y, and z values for street segment endpoints. Because the elevation values require three-dimensional geometries obtained from a large TIN, this dataset was created using the high-resolution Burnaby engineering TIN as a reference surface.



1. Close ArcCatalog, start ArcMap, and open a new map document. Load the Streets-Slope.lyr from \Burnaby2\GDBFiles\UTM83Z10\. If necessary, repair the data links by setting the data source to the Streets\_Slope\_Calc feature class. Save the map document as SlopeCalc.



- Zoom to the data extent and notice that all streets display as thin dark green lines. This line type suggests that they all have zero slope, but this exercise will fix that situation.



Initially, the street network displays as thin green lines indicating a slope value of zero.

- First, calculate the x and y coordinates of the segment endpoints by opening the attribute table for Streets\_Slope\_Calc. Locate the Start\_X field. Right-click on the field name and select Calculate Geometry.

- Click the Property drop-down and select X Coordinate of Line Start. Notice that endpoint coordinates and centroid coordinates can also be calculated.
- Because the data source and data frame use the same coordinate system, either coordinate system radio button can be clicked. Leave units as meters.
- Repeat this procedure to calculate the Y Coordinate of Line Start for Start\_Y, the X Coordinate of Line End for the End\_X field, and Y Coordinate of Line End for the End\_Y field.
- Next, use Calculate Geometry once more to calculate the Length for the Length\_Km field. Be sure to set units to kilometers. Save the map document.

### Calculating START\_Z and END\_Z

Because the Calculate Geometry functions do not directly calculate start and endpoint elevations, we need to calculate them separately. This calculation requires that line segments be three-dimensional entities, built using a grid or a TIN. Verify that these lines are true three-dimensional vectors by inspecting the Shape field in the attribute table, which contains a value of Polyline ZM. If you wish, you may also view them in ArcScene.

1. Calculate Z values for endpoints using the advanced VBScript provided in Listing 1 in a Map Calculator window. Locate [Start\_Z] and right-click its header. Select Field Calculator and check the Advanced box.
2. In the Field Calculator, check the Advanced box. In the Pre-LogicVBA Script Code window, type or paste the contents of Listing 1.
3. In the box below Start\_Z=, type z. Click OK.

```
dim pcurve as ipolycurve
set pcurve = [shape]
dim ppt as ipoint
set ppt = pcurve.frompoint
dim z as double
z = ppt.z
```

Listing 1: START\_Z calculation.

4. Repeat this calculation for [End\_Z] using the script in Listing 2.

```
dim pcurve as ipolycurve
set pcurve = [shape]
dim ppt as ipoint
set ppt = pcurve.topoint
dim z as double
z = ppt.z
```

Listing 2: END\_Z calculation.

5. Again, set the field value in the bottom window to z and click OK. (Hint: Preserve the advanced calculation, change "pcurve.frompoint" to "pcurve.topoint," and recalculate.) Save the map document. This procedure was provided by the ArcGIS 3D Analyst development team.

## Calculating Relative and Absolute Slope

With the x, y, and z coordinates calculated for the segment's start and endpoints, modeling relative slope is really quite easy. A combination of Pythagorean theorem and the rise over run slope formula will calculate percent slope between the two segment endpoints.

This procedure works well for short city street segments with a consistent slope. It does not work well for continuous looped features (although these can be split), long road intervals, or streets that traverse a sudden ridge or creek without a break. Investigations for the best ways to model these situations are ongoing.

Select [Slope1]; open another Field Calculator; and in the calculation window, type the expression in Listing 3.

```
(([End _ Z] - [Start _ Z]) / ((([Start _ X] - [End _ X])^2 + ([Start _ Y] - [End _ Y])^2)^0.5))*100
```

Listing 3: Calculate percent slope between two endpoints.

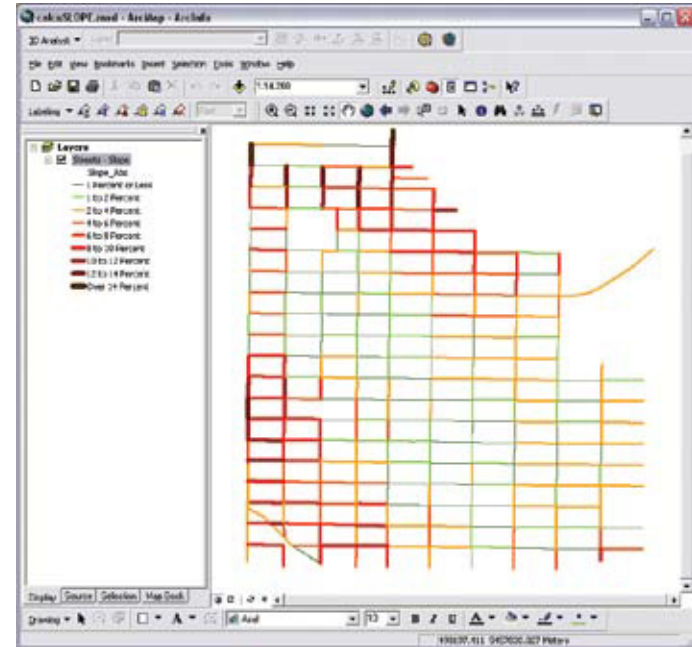
Notice that some slope values are positive (uphill travel) and some are negative (going downhill). Remember that the best way to think of slope as a percentage is that each value represents the number of meters (or feet) traveled up or down along a consistent 100-meter (feet) segment. Slopes of more than 6 percent require significant horsepower to travel up and considerable effort braking to go down.

Calculate absolute slope for the Slope\_Abs field with the Field calculator, using the formula in Listing 4. Save the map document.

```
Abs ([Slope1])
```

Listing 4: Calculating absolute slope.

Now that the Slope\_Abs field contains slope values, the street segments will be symbolized based on absolute slope.



After calculating the values for the absolute slope field, the street network will be symbolized based on values in the Slope\_Abs field.

## Conclusion

This workflow demonstrates how new geometry calculation features in ArcGIS 9.3 can calculate endpoint coordinates. It also highlights three-dimensional data conversion and several uses for tabular joins.

## Acknowledgments

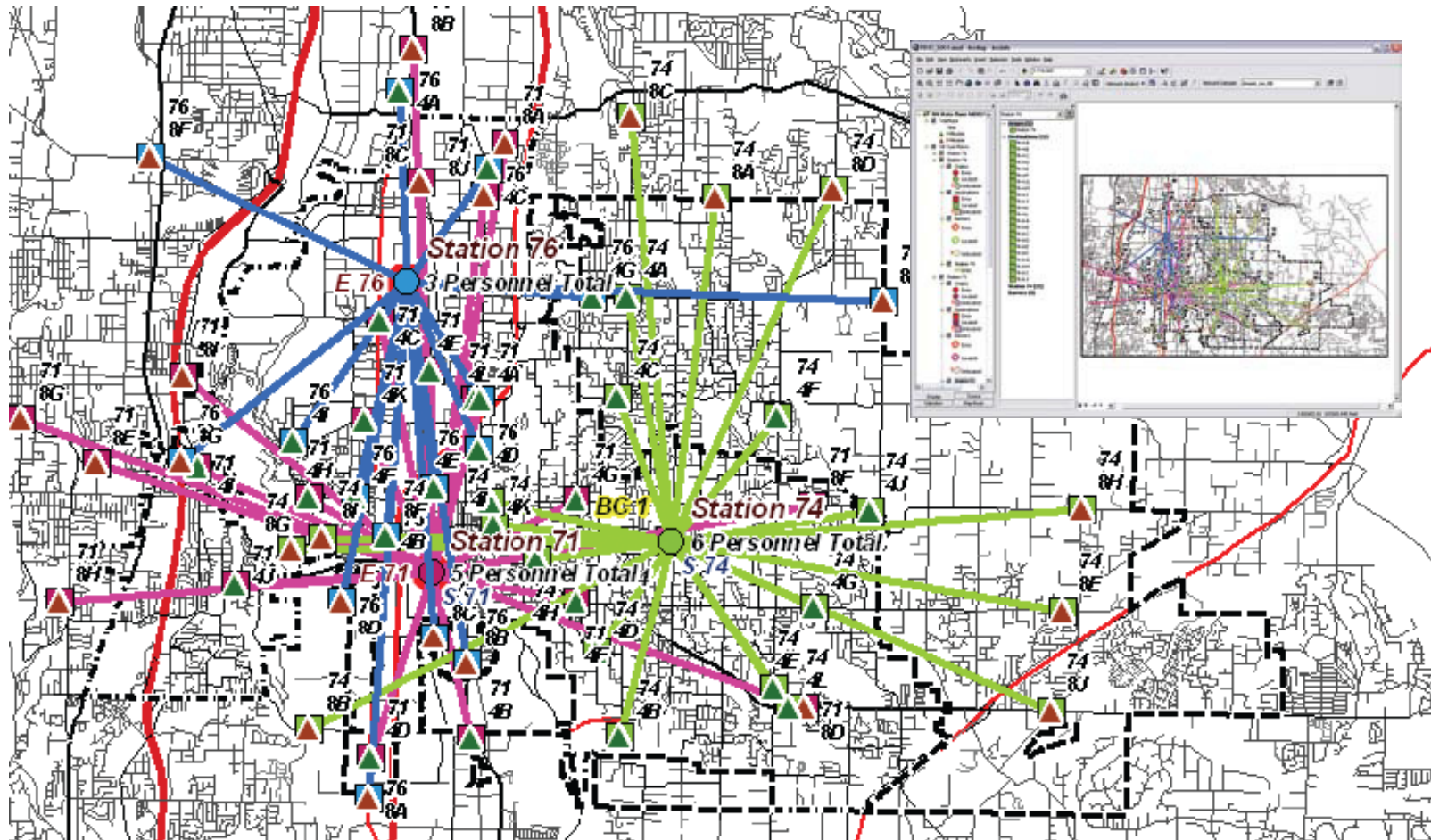
Special thanks to the Engineering Department staff of the City of Burnaby; the Esri 3D Analyst team; and Esri's Charlotte, North Carolina, Technical Support staff who helped develop the procedure for calculating elevation values with ArcGIS Desktop 9.3 and the ArcGIS 3D Analyst extension. Investigations of advanced procedures for modeling complex slope, both up and down hills, are continuing.

(This [article](#) originally appeared in the Winter 2009 issue of *ArcUser*.)

# Convincing the Chief

Proving that time-based networks really work

By Mike Price, Entrada/San Juan, Inc.



This exercise models data from Fire District 37 in South King County, Washington, and re-creates two analyses to validate the district's time-based network travel model using the ArcGIS Network Analyst extension's Cost OD (Origin-Destination) Matrix.

Many recent *ArcUser* articles have shown how to design, build, and run time- and distance-based travel networks for emergency response modeling. These models posted or customized speeds, global turn rules, and slope corrections. Previous articles assumed that the modeling parameters and analytical findings were correct.

This tutorial uses data from Fire District (FD) 37 in South King County, Washington, and re-creates two analyses that were recently performed by agency staff to validate the district's time-based network travel model. The ArcGIS Network Analyst extension's OD (Origin-Destination) Cost Matrix will be used to test and validate actual timed trial runs for several stations.

Previous tutorials that appeared in the July–September 2007, October–December 2007, and Summer 2008 issues of *ArcUser* can be used to review the ArcGIS Network Analyst modeling method and the concepts of distribution and concentration. These articles provide more information on how emergency responders use time as a response measure.

### What You Will Need

- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- Microsoft Excel
- ArcGIS Network Analyst extension
- [Sample dataset from ArcUser Online](#)

## Getting Started

To begin the exercise, visit the *ArcUser Online* Web site at [www.esri.com/arcuser](http://www.esri.com/arcuser) and download the sample dataset for this tutorial. This is the fourth in a series using Fire District 37 data, so the parent folder is named FD37\_4.

1. Unzip the [archived sample dataset](#) at or near the root directory of a local drive. The archive creates a folder called FD37\_4.
2. Open ArcCatalog and explore the data in FD37\_4. Notice that there are three subfolders named DBFFiles, SHPFiles, and Utility. All exercise data is registered in Washington State Plane NAD83 North Zone U.S. Feet (WASP83NF).
3. Inside SHPFiles, notice the WASP83NF folder. This shapefile subfolder contains several shapefiles and layer files that will be used in this exercise.
4. Inspect the DBFFiles folder and see that Time\_Runs\_1 contains run data for four FD 37 fire stations, recorded at four- and eight-minute travel points.
5. Open RunSummary1.xls and see that it contains one worksheet, Statistical Summaries, that is ready to tabulate statistics for the four- and eight-minute runs for each station.
6. Leave ArcCatalog open.

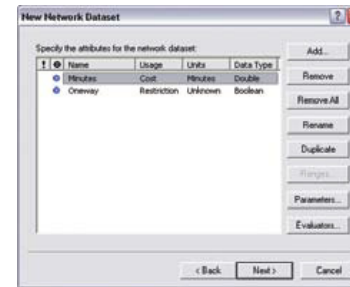


To gather data for this project, station duty crews at each station were instructed to drive 10 different routes from their station to locations on the street network. They drove the routes at speeds at or near accepted response speeds, in light to moderate daytime traffic, and in good weather. The apparatus officer noted the exact location of the four-minute and eight-minute time point on each route. These time points were then mapped and are available for this exercise as a dBASE table including WASP83NF coordinates.

## Building a Network Dataset with Network Analyst 9.3

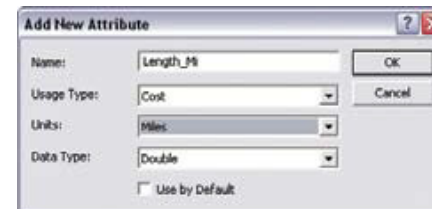
In ArcCatalog, verify that the Network Analyst extension is available and active.

1. Navigate to FD37\_4/SHPFiles/ WASP83NF and locate streets\_nw.shp. Preview the attribute table for this layer. Notice that it contains network-ready data including fields for a time cost in minutes, length in miles, and one-way flags. These fields will be used to build a network dataset.
2. In the Catalog tree, right-click streets\_nw.shp and select New Network Dataset. Accept the default name and click Next.



In ArcCatalog, create a new network dataset.

3. Inspect Connectivity and accept End Point as the only connector; click Next. The streets use geometry rather than elevation to define crossing relationships, so do not modify connectivity.
4. Click Next and accept Global Turns; click Next again.
5. In the network attributes window, click the Add button to add an attribute. In the new Add New Attribute dialog box, type Length\_Mi for Attribute, choose Cost for Usage Type, choose Miles for Units, and leave Data Type as Double. Notice that Minutes and Oneway are both default parameters because the primary test will be fastest travel time, not the shortest distance.



Create a new attribute, Length\_Mi, for this network dataset with Cost as the Usage Type and Miles as the Units.

- Highlight Minutes and click the Evaluators button. In the Evaluators dialog box, select the Default Values tab. For the Turn element, click on the word Constant to see four options. These options now include a new one in ArcGIS 9.3 called Global Turn Delay. Select this option and press F12.

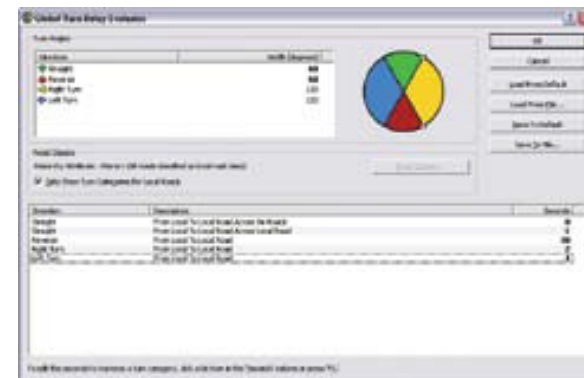


Set the default values for the Minutes evaluator and use the new Global Turn Delay for the type of turn.

- A new Global Turn Delay Evaluator appears. Notice that this evaluator supplies defaults but allows modification of the intersection approach angles and the delay times. Also notice that feature classes can be used to create complex relationships between different street classes.

- Save the map document.

The streets in this sample dataset are rather simple and will only require the use of one Local class. The Seconds field in this dialog box accepts values for delays for straight travel (with and without crossing roads), right and left turns, and U-turns. After tuning the streets in the sample dataset, it was determined that the delays shown in Table 1 work best throughout the district.



Set the Seconds delays field values in the Global Turn Delay evaluator as shown here and listed in Table 1.

Table 1: Delay values.

Direction	Description	Sec
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	3-
Right Turn	From Local to Local Road	2
Left Turn	From Local to Local Road	4

To add these values to this project, type the values for these delay values into the Seconds field, or load a prebuilt XML time set from the \Utility folder created by the sample dataset archive. To load the XML file, click the Load From File button on the dialog box, navigate to \Utility, and select GlobalTurns\_00\_01\_02\_04.xml. The optimal values will post automatically.

Turn window width can be changed interactively. After using the mouse to resize portions of the colorful azimuth graphic, reset or retype Width values (in degrees) to restore the defaults or reload the XML file. Click OK to close the Global Turn Delay Evaluator, click OK to accept the updated Evaluators, and click Next. Accept Driving Direction defaults and click Next again.

A summary of the network dataset parameters that have been set appears in a scrolling window. Select and copy this text into a WordPad file. Name the file with the creation or last modification date and save the text file in the \SHPFiles\WASP83NF folder. Inspect this file carefully and observe the new global turn rules.

Click Finish, then Yes to build the new network dataset. Once this is completed, close ArcCatalog and open ArcMap.

## Loading and Mapping Network Streets and Time Runs

In ArcMap, open the FD37\_SOC4 ArcMap document file located in the FD37\_4 root folder. Inspect this map document. The data is very similar to data used in previous District 37 tutorials. However, in this case, only three stations appear. These stations were selected to show variety within the district. The project opens in Layout View and shows location, apparatus, and staffing for Stations 71, 74, and 76. The Time Runs layer, at the top of the TOC, does not have a valid data connection. At the end of this next process, that problem will be fixed.

Station 71 is an engine/squad station with five on-duty personnel. It is located just south of the Kent downtown area. Station 74 includes a ladder, a squad, and a battalion chief (six personnel), located on high ground in eastern Kent. It is situated on an arterial street and much of the surrounding land use is residential. Station 76 is a three-firefighter engine station located in the northern Warehouse district.

1. Before adding data to the project, confirm that the Network Analyst extension is available and its toolbar is visible.
2. Open an empty Network Analyst Window. Click the Add Data button on the Standard toolbar and navigate to \SHPFiles\WASP83NF.
3. Load the network dataset streets\_nw\_ND. When prompted, do not load other participating feature classes.
4. In the TOC, drag streets\_nw\_ND below the Network Streets and turn it off.
5. Navigate to the \DBFFiles folder and load Trial\_Runs\_1.dbf.
6. Open the table for this file and locate the East and North fields. Using these and applying the correct Washington State Plane coordinates, the data can be registered.
7. In the TOC, right-click Trial\_Runs\_1.dbf and choose Display XY Data. Set the X Field to East and the Y Field to North. Click Edit.
8. In the Spatial Reference Properties dialog box, click Select and specify NAD\_1983\_State Plane\_Washington\_North\_FIPS\_4601\_Feet from the choices under Projected as the coordinate system. Click OK and OK to exit both dialog boxes.



Create an events layer from Time\_Runs\_1.dbf and export the georeferenced data to a shapefile.

9. After Trial\_Runs\_\_1Events loads, rightclick on it and choose Data > Export Data. Apply the data frame's coordinate system, name it Trial\_Runs\_1.shp, and store the file in \SHPFiles\WASP83NF. Do not add the shapefile to the data frame.
10. Next, double-click on Time Runs, the layer that has a broken data connection, and set Trail\_Runs\_1.shp as its data source. Remove Trial\_Runs\_\_1Events.

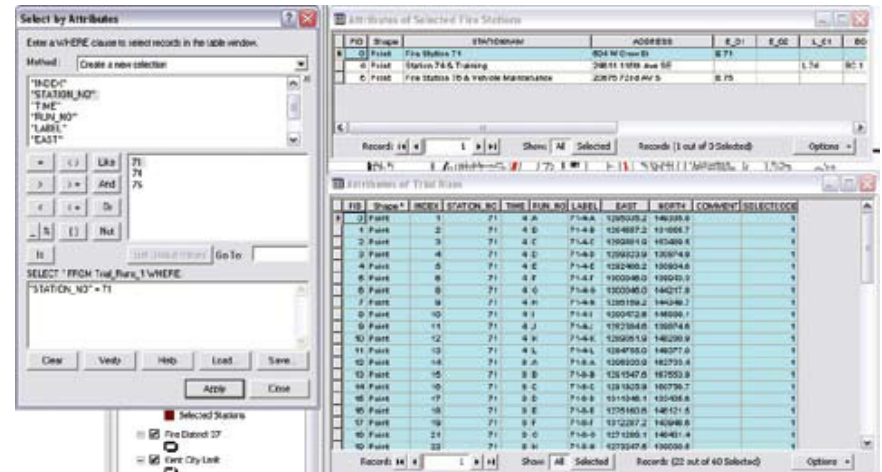
11. Make the Trial Runs layer visible and inspect its points. Each point is labeled to show the station, time interval, and run code. Switch from Layout View to Data View.
12. Save the project.

## Building and Solving an OD Cost Matrix for Station 71

The next task will be building three origin-destination matrices—one for each station and its time run data. There are many ways to build and analyze this run data, but creating a separate matrix for each station will allow quick viewing of statistical data for each time subset. There are more sophisticated ways to model and present this data, but this exercise uses a simplified approach. After creating the matrix for Station 71, the process will be repeated for Stations 74 and 76.

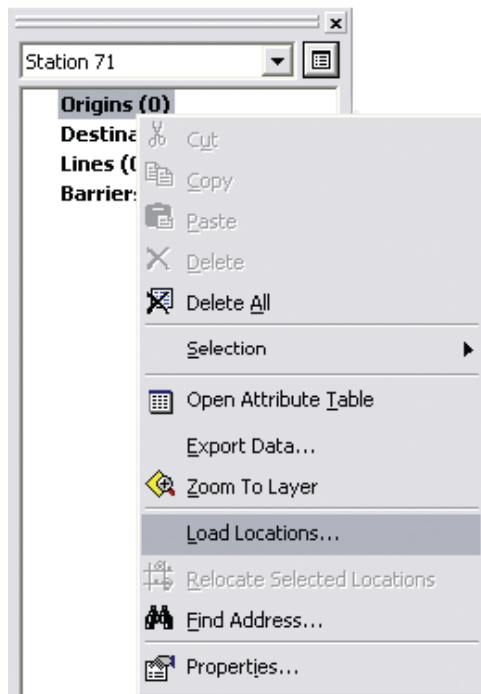
1. Be sure that the Network Analyst toolbar and window are available. Click on the Network Analyst drop-down in the toolbar window and choose New OD Cost Matrix.

2. In the TOC, right-click on OD Cost Matrix (just created) and select Properties. In the General tab, rename the layer Station 71. Click the Accumulation tab and check the Length\_Mi and Minutes boxes. In the Analysis Settings tab, verify that Impedance is set to Minutes.



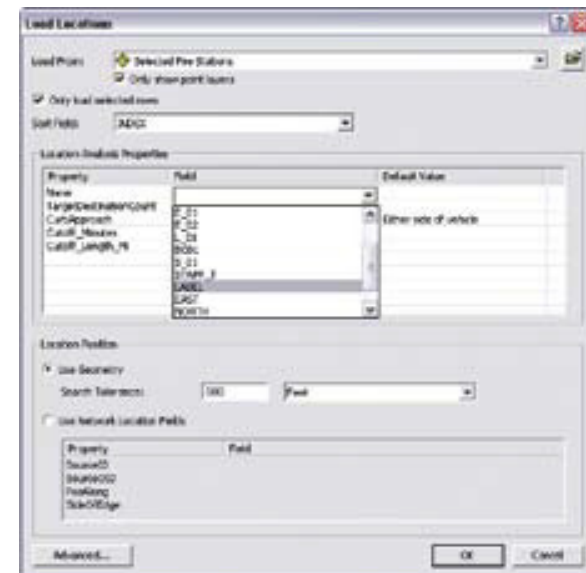
In the Selected Fire Stations table, select the only record for Station 71. In the Trial Runs table, use an attribute query to highlight all 22 records for Station 71.

- Open attribute tables for Time Runs and Selected Fire Stations layers. In the Selected Stations table, select the only record for Station 71. In the Trial Runs table, use an attribute query to highlight all 22 records for Station 71.



In the Network Analyst window, load the locations in the OD Cost Matrix for Station 71 by right-clicking on Origins and choosing Load Locations.

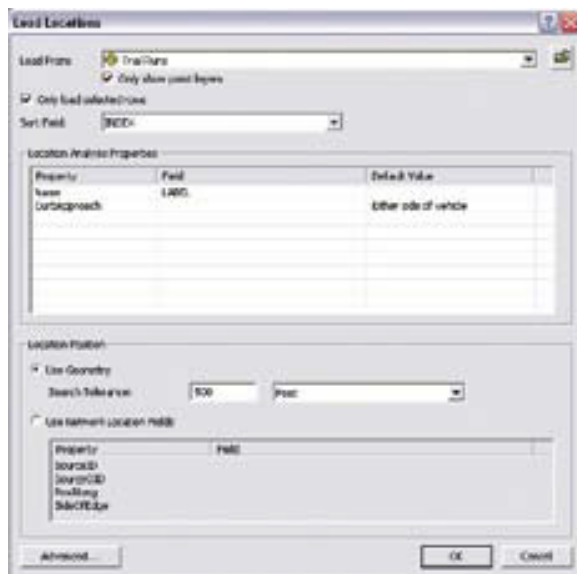
- In the Network Analyst window, right-click on Origins and select Load Locations. In the Load Locations dialog box, set Sort Field to INDEX. For the Name Property, click on Field and choose LABEL. Under Location Position, choose Use geometry and specify 500 and Feet for the search tolerance. Click OK. Verify that the single Station 71 record in Selected Fire Stations is selected.



In the Load Locations dialog box for Selected Fire Stations, set Sort Field to INDEX, set the field for Name property as LABEL, and under Location Position, choose Use Geometry and specify 500 and Feet for the search tolerance.



- Right-click on Destinations, choose Load Locations, and select the 22 records for Station 71 selected in the Trial Runs attribute table. In the Load Locations dialog box, set Sort Field to INDEX and the Name property field to LABEL. Be sure that the correct (i.e., selected) 22 records load. If non-Station 71 records load, delete them and reload the correct ones. (Note: Do not delete records when modeling Concentration because the tabular join to INDEX, necessary for this operation, will fail.)



Right-click on Destinations, choose Load Locations, and select the 22 records for Station 71 selected in the Trial Runs attribute table. In the Load Locations dialog box, set Sort Field to INDEX and the Name property field to LABEL.

- Create new OD Matrices for Stations 74 and 76 using this procedure. Be sure to select and load the correct origin and destination records. Rename each OD matrix and group all matrices in one group layer named OD Cost Matrix Group.
- Save the project.

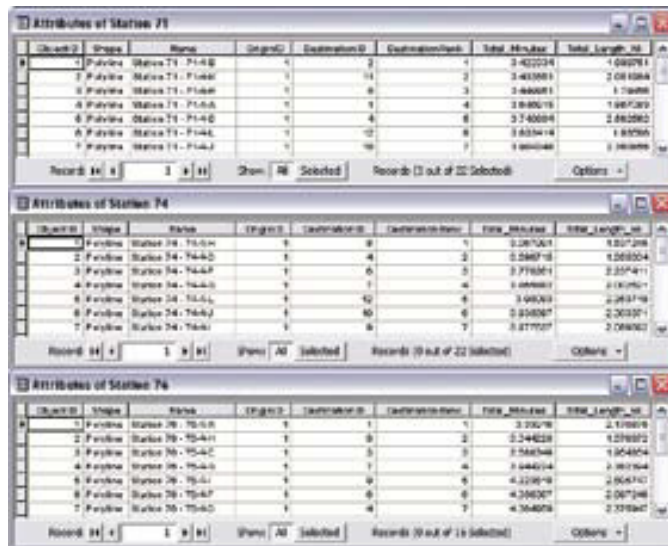
## Solving and Analyzing OD Cost Matrix Results

The three matrices are now ready to solve.

- In the OD Matrix group, right-click on the matrix for Station 71 and select Solve. Under Destinations, Lines will be populated.
- Right-click on Lines, choose Properties, and use the General tab to rename it Station 71. Using Properties, also change the line width to a three-point width and apply bright distinct colors.
- Repeat this process for the Station 74 and 76 matrices.
- Save the map document again.

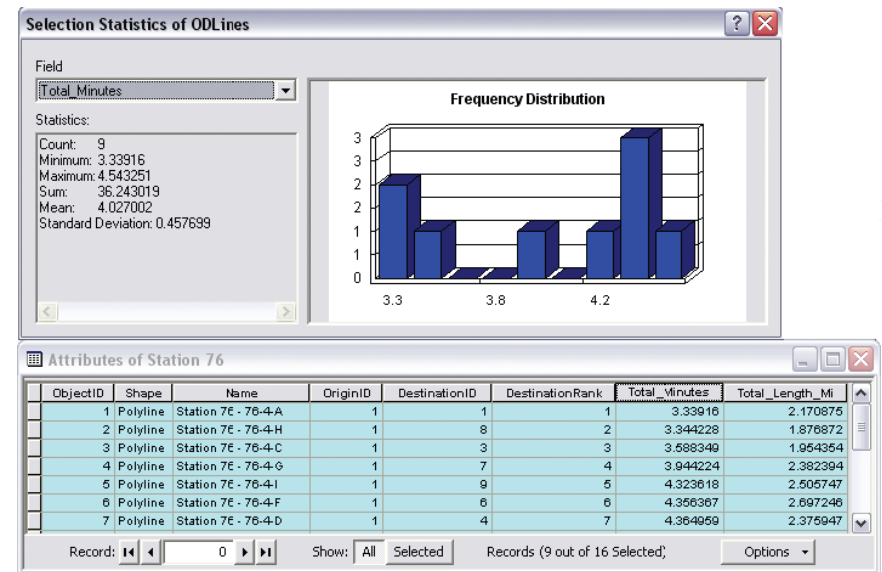
This exercise builds two-node vector lines that show the connection between a fire station and its trial run points. Network Analyst actually posts the shortest travel time and route distance in the Lines table. Although the route is represented by a straight line, it actually follows the fastest network.

1. Under the OD Cost Matrix group, right-click on the Lines solution for each station and open its attribute table. Stack the tables. Select the four-minute records for each station by querying out records with Total\_Minutes less than 5.0.



Under the OD Cost Matrix group, right-click on the Lines solution for each station and open its attribute table. Stack the tables.

2. To quickly tabulate and display statistics for each station's four-minute runs, locate and right-click on each table's Total\_Minutes field and choose Statistics.



To quickly tabulate and display statistics for each station's four-minute runs, locate and right-click on each table's Total\_Minutes field and choose Statistics.

- Inspect the statistics for the sub-four-minute runs for each table, particularly the Mean and Standard Deviation values.

It certainly would be nice to place this data in a table so it could be studied. To quickly post this summary data, open the Excel spreadsheet template, RunSummary1.xls, provided in the sample dataset, and copy values from the four-minute statistics generated for each station to the appropriate cells in the spreadsheet.

	A	B	C	D	E	F	G
1	Station	Run Time, Minutes	Run Count	Minimum, Minutes	Maximum, Minutes	Mean, Minutes	Standard Deviation
2	71	4.0	12	3.4223	4.6206	3.9917	0.4525
3	74	4.0	11	3.0680	4.3289	3.8934	0.3255
4	76	4.0	9	3.3392	4.5433	4.0270	0.4577
5							
6	71	8.0	10	6.2138	8.5308	7.8121	0.7505
7	74	8.0	11	5.1552	8.8400	7.6907	0.9697
8	76	8.0	7	6.5332	8.6655	7.9238	0.7880

To quickly post this summary data, open the Excel spreadsheet template, RunSummary1.xls, provided in the sample dataset and copy values from the four-minute and eight-minute statistics generated for each station to the appropriate cells in the spreadsheet.

In ArcMap, under the four-minute statistics for Station 71, copy and paste the Mean value from the summary spreadsheet to the Mean, Minutes field in the attribute table for Station 71 in ArcMap. Repeat for the Run Count; Maximum, Minutes; Minimum, Minutes; and Standard Deviation fields. Gather the same statistical data for Stations 74 and 76.

To generate statistics for the eight-minute run data for each station, simply click the Options tab on the table for each station and choose Switch Selection. Copy and paste the eight-minute run statistics into the spreadsheet.

Now that the time Runs for three District 37 fire stations have been summarized, inspect RunSummary1.xls. Notice that the mean values for all four- and eight-minute runs are very close to the target times. In each station's travel area, the average actual time is very close to the targets. Each station's dataset includes records that represent times greater than and less than the targets. Smaller standard deviation values suggest tighter clustering around the mean. In general, District 37 managers are very satisfied with the performance of this travel network. These trial runs have shown that slightly liberal turn rules and posted speed are valid measures of emergency response capability.

## Summary

This exercise used the Network Analyst OD Cost Matrix to compare actual measured travel times to modeled values. Overall, this analysis demonstrated a very good correlation between modeled and actual times. District 37 personnel continue assessing travel times and testing additional details that might improve the response model. As a corollary to this exercise, District 37 has also recognized the potential to use an OD cost matrix to test and validate actual travel times to specific incidents.

## Acknowledgments

Special thanks go to the administration and staff of Fire District 37, South King County, Washington, and the many FD 37 and Kent City staff who provided data for this exercise.

This allowed the mapping and evaluation of actual run time data captured by district firefighters and modeled real travel time data on city streets.

(This [article](#) originally appeared in the Spring 2009 issue of *ArcUser*.)

# Do It Yourself!

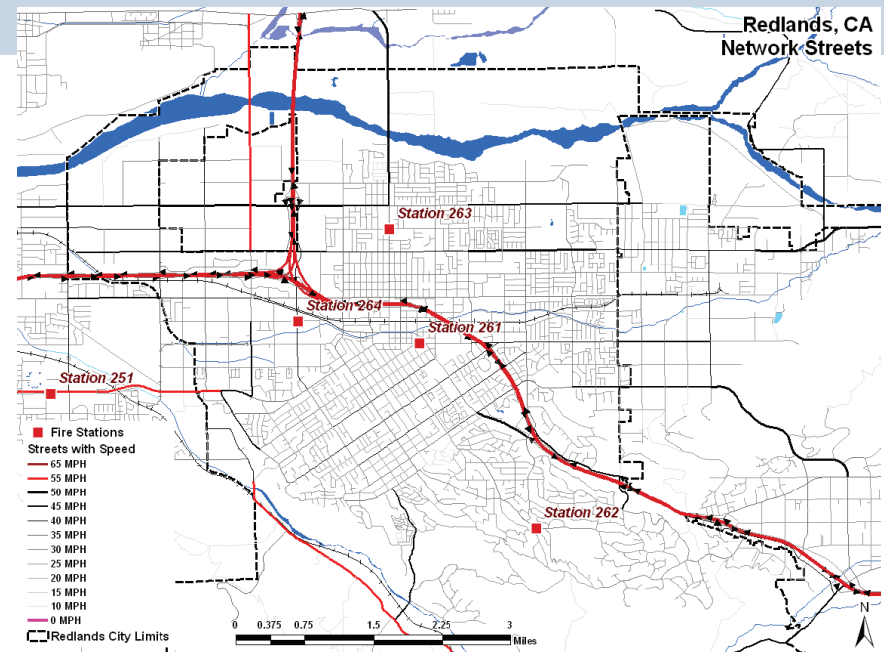
Building a network dataset from local agency data

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



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

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 [esri.com/arcuser](http://esri.com/arcuser). These articles provide



background information on how emergency responders use time as a response measure.



### What You Will Need

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

## Getting Started

To obtain the sample dataset for this exercise, and download [doityourself.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 ADDR\_CITY. 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.

## 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

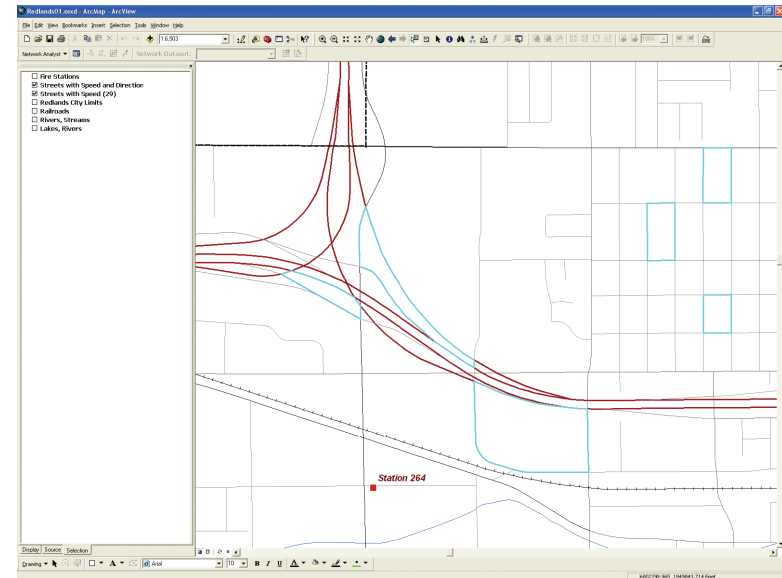
Because this is a geocoding dataset, it does not contain fields for nonintersecting crossings (which are also called z-elevations). Although two z-elevation fields could be added to this table, it would require careful editing of all the values for each crossing and intersecting street segment—a complex,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

## 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



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

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.

## 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.

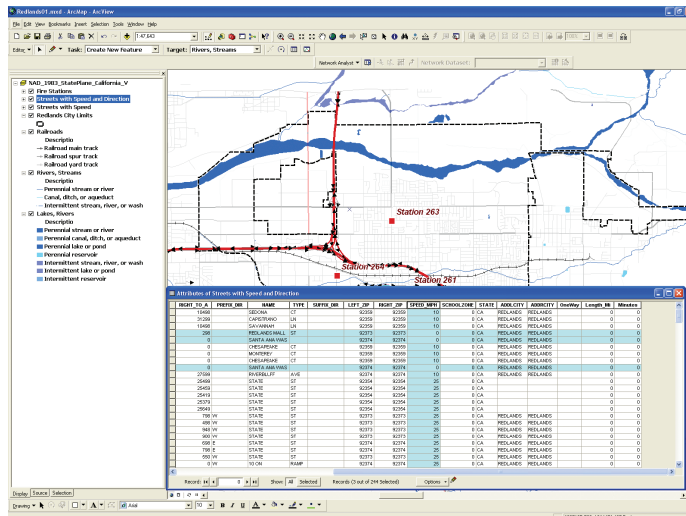
## Editing the Streets with Speed and Direction Layer

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.

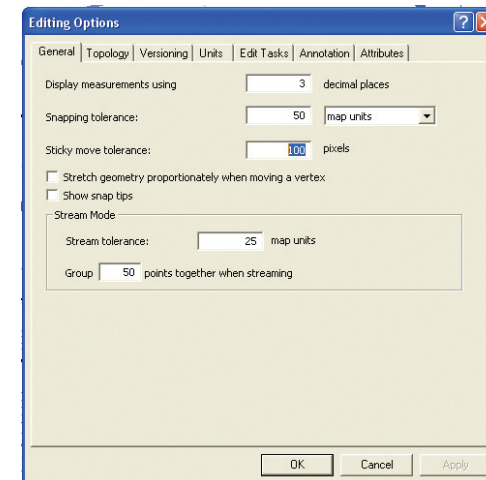
Delete Redlands Mall and the Santa Ana Wash; set all other speeds to 10 mph.



## Directionality

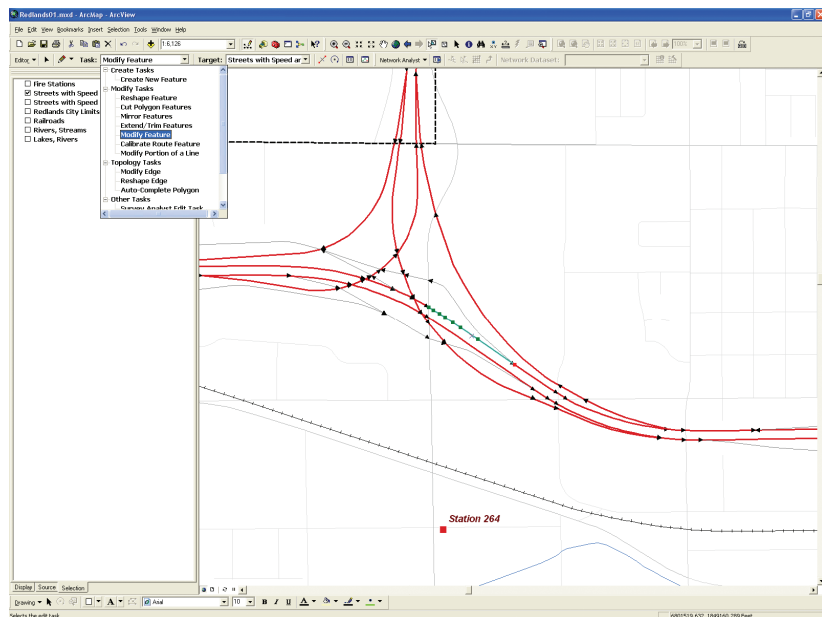
Now to properly orient all freeway and ramp street segments. There are several segments of one-way streets in downtown Redlands that will be validated.

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.



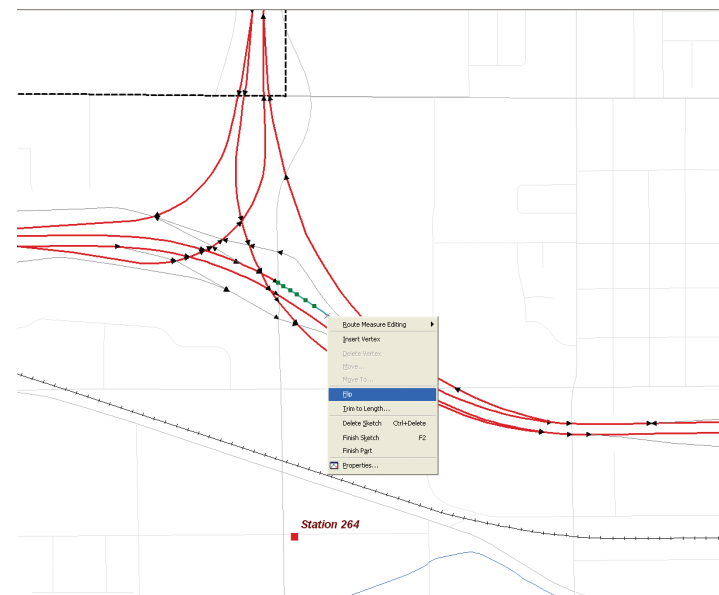
Set the snapping tolerance to 50 feet and the sticky move tolerance to 100 pixels.

- 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 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.

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



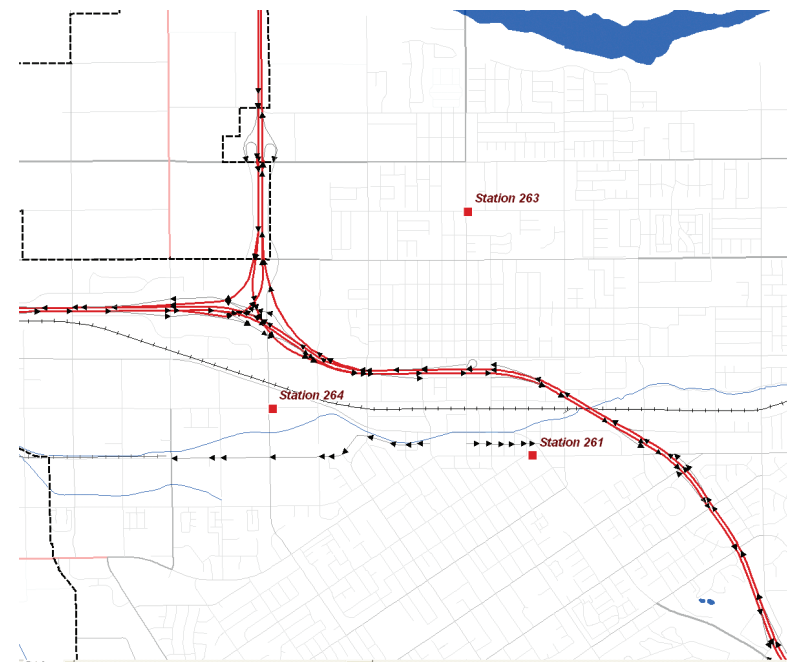
Carefully position the mouse cursor tip near the line's midpoint. (Hint: Look for the small x.) Right-click and select Flip from the context menu. Watch as the red leading node swaps ends, indicating that the line has reversed direction.

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.
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.



A properly oriented network.

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 line 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.

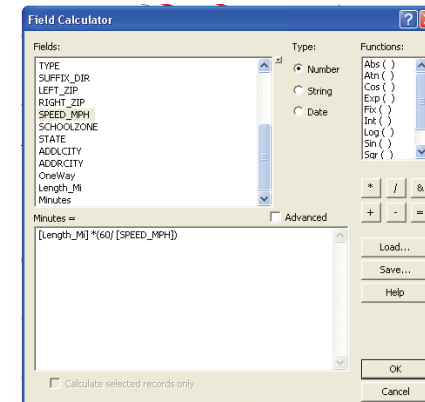
4. With length in miles, travel time in minutes can now be calculated. Open the Field Calculator. Select the MINUTES field and type the following in the formula box:

$[Length\_Mi] * (60 / [SPEED\_MPH])$

Click OK and check the calculations.

RIGHT_TO_A	PREFIX_DIR	NAME	TYPE	SUFFIX_DIR	LEFT_ZIP	RIGHT_ZIP	SPEED_MPH	SCHOOLZONE	STATE	ADDLCITY	ADDRCCITY	OneWay	Length_Mi	Minutes
0	E		FRWY		92354	92354	65	0	CA	REDLANDS	REDLANDS		0.694301	0
0	E		FRWY		92408	92408	65	0	CA	REDLANDS	REDLANDS		0.35406	0
0	E		FRWY		92400	92400	65	0	CA	REDLANDS	REDLANDS		0.132561	0
0	E		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.981627	0
0	E		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.803742	0
0	E		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.366659	0
0	E		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.552608	0
0	E		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.841648	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.723612	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.172258	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.333113	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.449164	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.816986	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.729463	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.825621	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.749994	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.172963	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.155004	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.201332	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.777206	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.399163	0
0	W		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		0.304022	0
0	E		FRWY		92374	92374	65	0	CA	REDLANDS	REDLANDS		1.844219	0
0	E		FRWY	W	92374	92374	65	0	CA	REDLANDS	REDLANDS		0.990274	0

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.

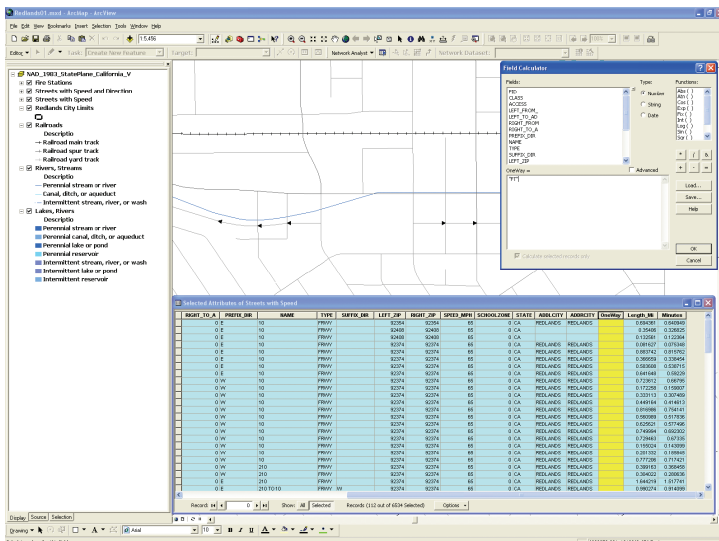


- Now, assign a OneWay code to all limited-access streets. Close the Streets with Speed attribute table and open the Streets with Speed and Direction attribute table. This layer also references the streets\_nw shapefile, filtered to show only limited-access streets and a subset of Redlands streets.
-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

- 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.



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.

## 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.

(This [article](#) originally appeared in the Summer 2009 issue of *ArcUser*.)

# Run Orders

Modeling and mapping public safety arrival orders

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.

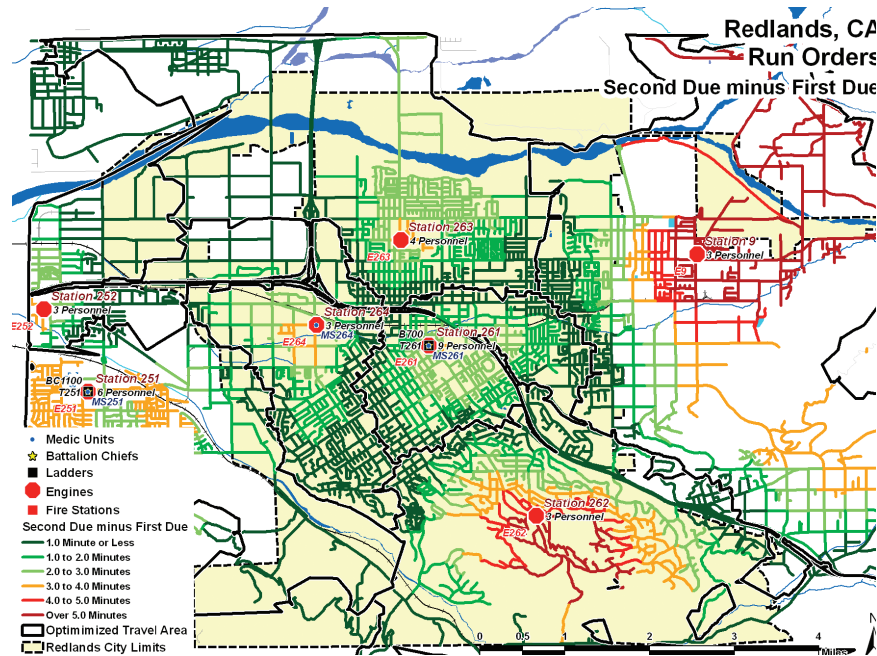
Run orders allow a public safety agency to predict and map the arrival sequence and times for responders traveling to an incident from multiple locations. Previous exercises in *ArcUser* used optimized travel areas generated using the ArcGIS Network Analyst extension to identify the station from which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

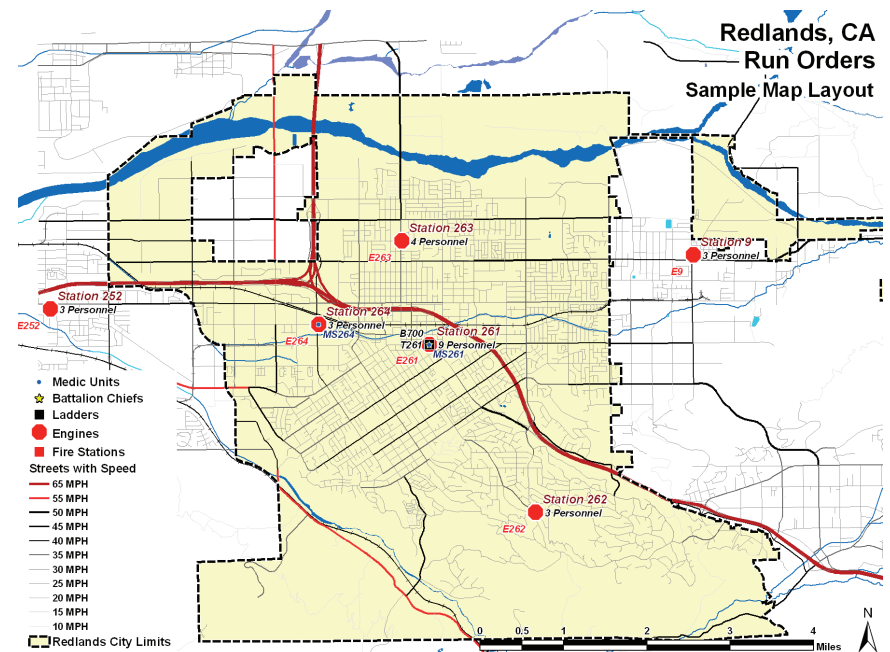
exercises in this series, visit the Learn How to Model Networks page ([www.esri.com/news/arcuser/avmodel.html](http://www.esri.com/news/arcuser/avmodel.html)).



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.

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 models response from fire stations in and near Esri's headquarters in Redlands, California.

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.

#### 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

## Getting Started

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.

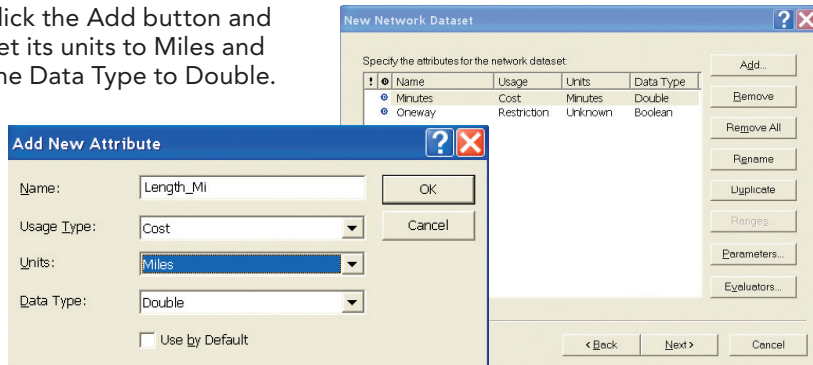
## Building the Network Dataset

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.



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.



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.

Table 1: Delay parameters.

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

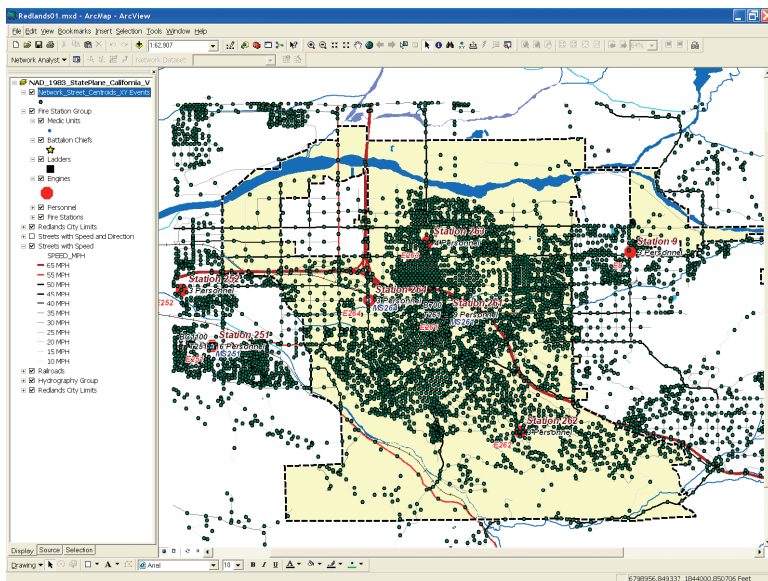
5. Click Next to continue and accept the directions defaults.

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.

- 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.



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.

## 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.

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

- In the TOC, place Run\_Order\_Model\_ND just below Streets with Speed layer and make it not visible.
- 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.
- 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.

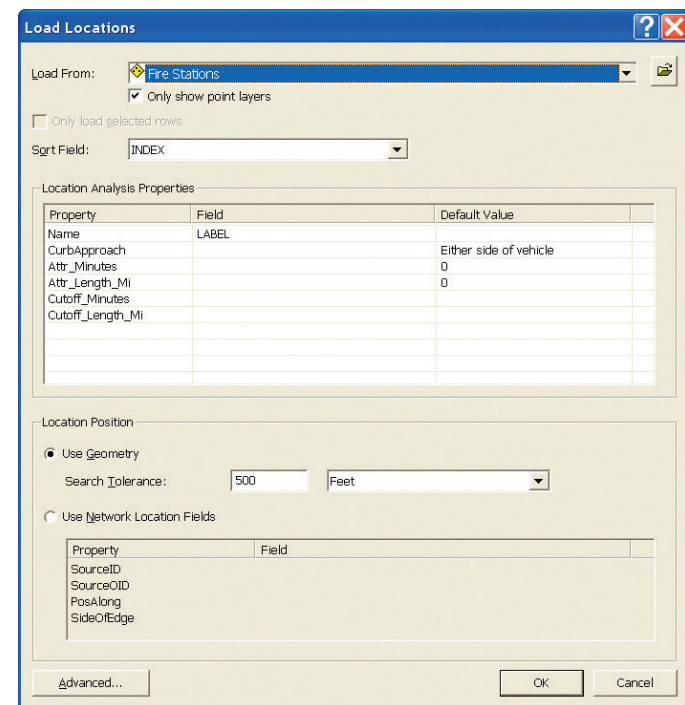
**Table 2: Facilities loading parameters.**

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

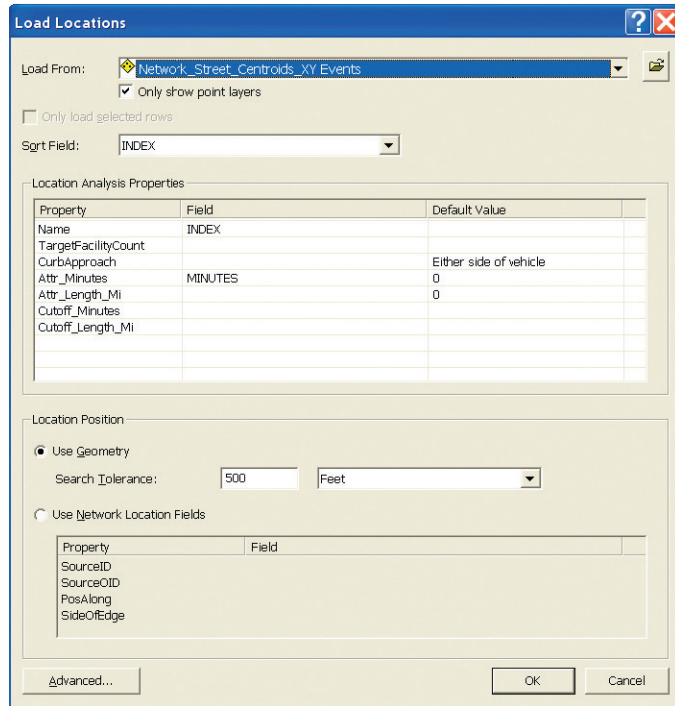
- Right-click on Incidents and choose Load Locations. Carefully apply the loading parameters listed in Table 3 and click OK. This may take considerable time, so be patient. If the process hangs, close ArcMap, reopen the last saved project, and load it again. Inspect the loaded incident data. If it is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

**Table 3: Incident loading parameters.**

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



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

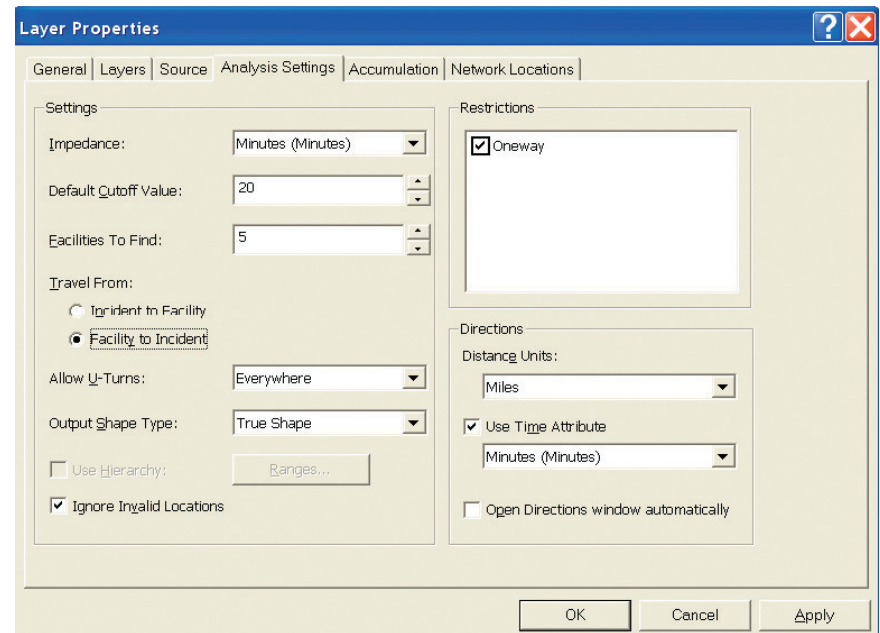


Carefully fill out the dialog box when loading the Network\_Street\_Centroids\_XY.dbf for Closest Facility analysis.

## 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

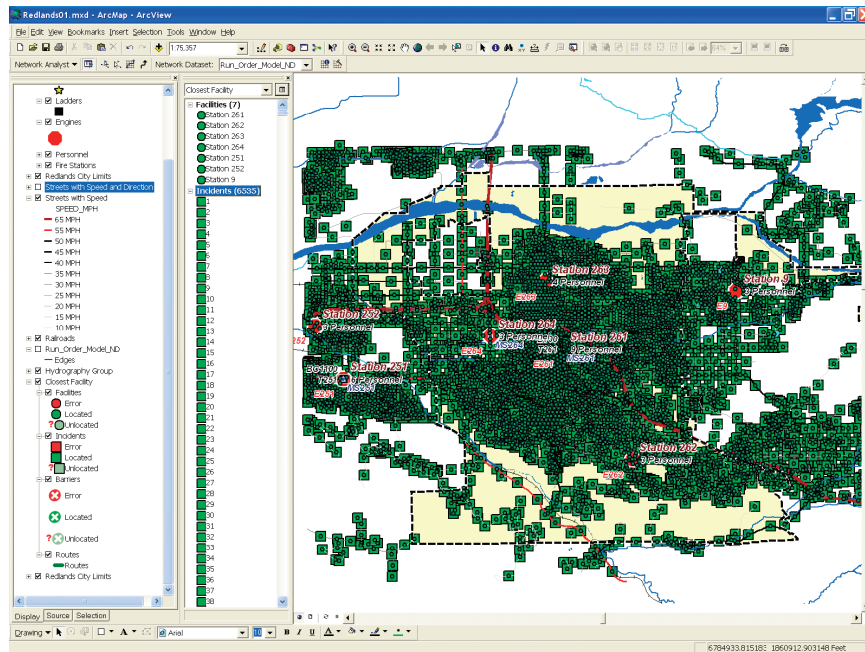
Value to 20, and Facilities to Find to 5. Change Travel from to Facility to Incident. Accept defaults for all other parameters.



Carefully set the Closest Facility Solver parameters.

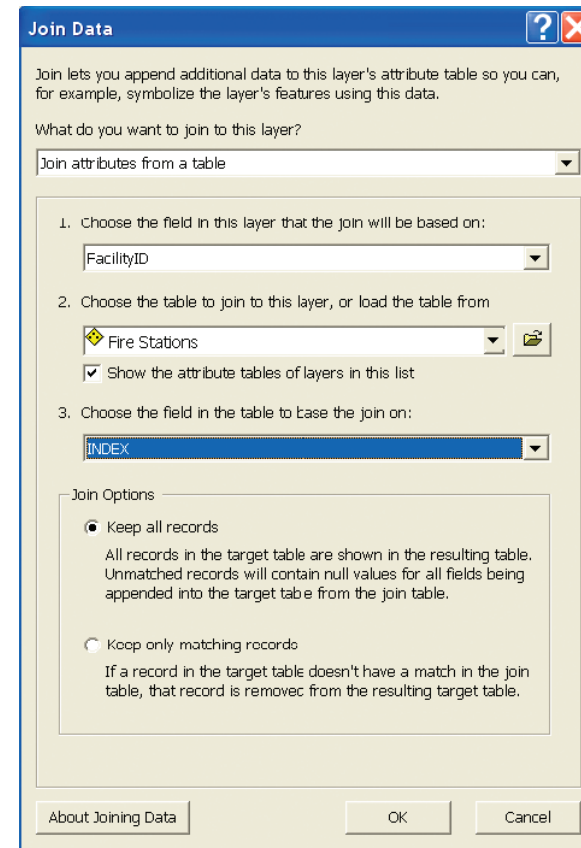
3. In the Accumulation tab, check the Length\_ Mi and Minutes attributes. Click Apply to save these parameters. Click OK. Save the project. In the TOC, right-click on Closest Facility and choose Solve. Now it's time to take a break. There are literally thousands of routes in this solution so this process 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.



Be patient while several thousand centroids load.

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.



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

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

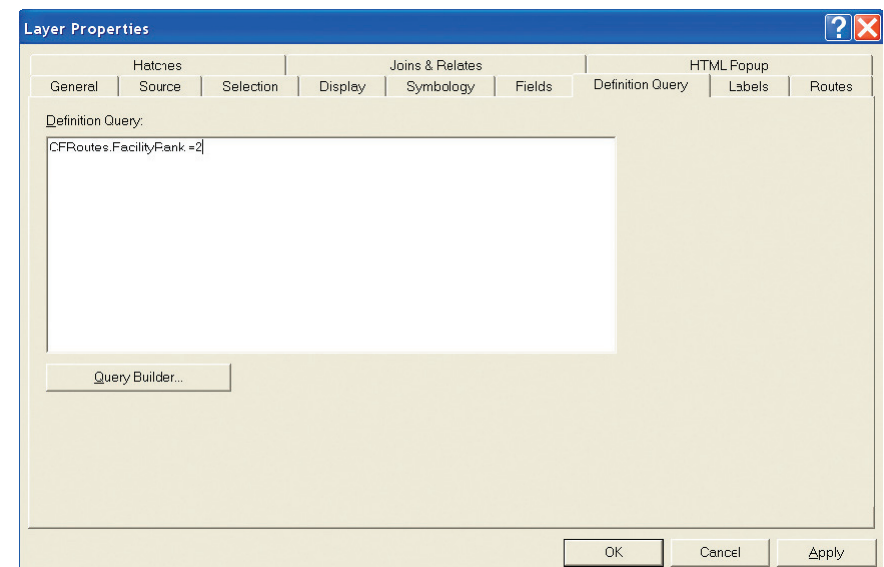
With the Station Number (STATION\_N) for up to five responders for each modeled street segment, the next step is the crux of this entire procedure.

## 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

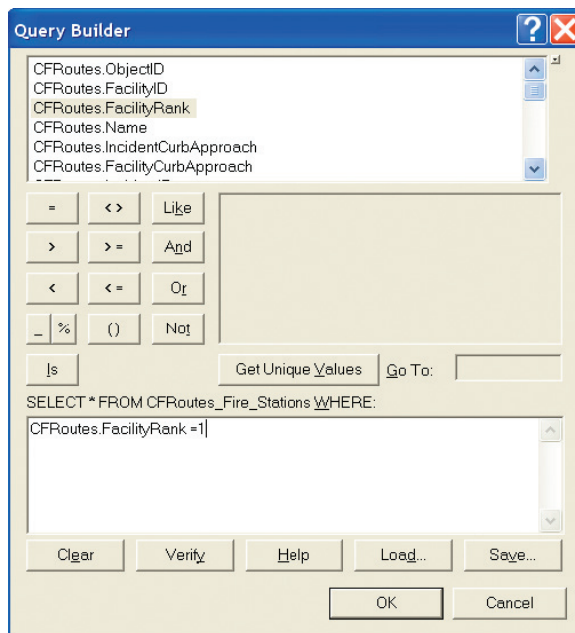
filter the Routes attributes by arrival and export each subset to a separate dBASE table.

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.



In the TOC, right-click on Routes, Choose Properties, and select Definition Query.





In the formula box, request all records where `CFRoutes.FacilityRank = 1`.

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.

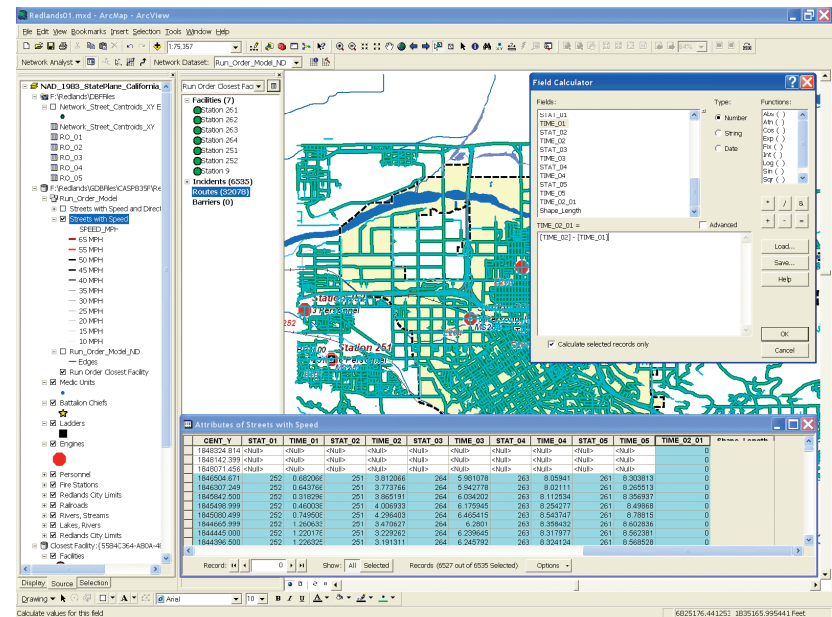
## Populating Station and Time Fields with Joined Table Data

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.



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

## 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

Thanks to Chief Jeff Frazier and his staff at the Redlands Fire Department for providing fire station apparatus and personnel information and the staff of the City of Redlands GIS for the use of their excellent data. Special thanks to Tom Patterson and Russ Johnson at Esri for helping make this exercise a reality.

For more information, take the Esri instructor-led course *Working with ArcGIS Network Analyst*.

(This [article](#) originally appeared in the Fall 2009 issue of *ArcUser*.)

# It's All About Streets

Tips and tricks for obtaining, building, and maintaining time-based network streets

By Mike Price, Entrada/San Juan, Inc.

*Editor's note: Mike Price has been a regular contributor of articles on creating models with GIS since this magazine's inaugural year. Over the last two years, he has authored a series on modeling street network data for public safety applications using the ArcGIS Network Analyst extension. In this article, he shares the data requirements for this type of modeling and tips he has discovered over the years for enhancing and managing those datasets.*

It's often said, "Time is of the essence." This is certainly true when it comes to modeling networks for public safety response.

I now believe that finding/creating and supporting an accurate, reliable street network is the single most important part of building and using any public safety model. Unfortunately, locating or creating a network-ready street set that is current, is complete, and contains the necessary attribution is not easy.

Here are some tips and tricks that I use to find, enhance, and maintain a quality network street dataset. If you are new to modeling networks with ArcGIS Network Analyst or would like a refresher course on time-based response modeling, visit the [Learn How to Model Networks](#) page.

When I model networks, I may use one of four different street data sources: simple Census TIGER streets, StreetMap in the Esri Data & Maps DVD set that comes with ArcGIS, commercial network products, and customized datasets that are often built by a local jurisdiction or its GIS partner. Here is a brief summary of these data types.

## Census TIGER Streets

TIGER streets, part of Census 2000 TIGER/Line Data, is a free source for streets. County TIGER streets may be downloaded from Esri's Free Data Web page ([www.esri.com/freedata](http://www.esri.com/freedata)). The Census 2000 TIGER streets are outdated, and I'm waiting for the Census 2010 update. TIGER spatial geometries are approximate and they do not directly contain time impedance. The Census Feature Class Code (CFCC) may be joined to the streets to obtain typical speeds. For an early tutorial on using Census TIGER streets, see "[Taming TIGER Data](#)."

## Esri Streets

For years, Esri has provided StreetMap in *Esri Data & Maps*, which ships with ArcGIS. To see these streets, locate the StreetMap

DVD on a current *Esri Data & Maps* DVD set. These streets do include speed limits but compare this information with local signage. You may want to clip your favorite areas and save them as shapefiles or file geodatabases. Esri also sells StreetMap Premium ([esri.com/data/streetmap](http://esri.com/data/streetmap)), which provides streets that readily support geocoding and routing. Point-to-point routing is also available through the ArcGIS Online routing service.

## Commercial Streets

Tele Atlas/TomTom and NAVTEQ are the two major commercial network street providers in North America. Commercial streets are available by subscription and include periodic updates. Vendors of street data also encourage users to provide current content.

Tele Atlas/TomTom provides digital maps and dynamic content that power essential navigation and location-based services. The company provides several products, including its MultiNet geocoding and routing dataset. MultiNet streets incorporate a full suite of capabilities, allowing users to locate the people and services they need quickly; reach their destinations via safe, reliable, and customizable routes; and use the clearest, most visually compelling maps available. Check out the MultiNet streets at [www.teleatlas.com/OurProducts/MapData/Multinet/index.htm](http://www.teleatlas.com/OurProducts/MapData/Multinet/index.htm).

NAVTEQ provides high-quality street data to partner developers that incorporate it into many applications. Visit NAVTEQ Map online at [www.navteq.com](http://www.navteq.com) or contact NAVTEQ and find a partner vendor that can provide data for local needs.

## Custom Street Datasets

Local agencies often create their own street centerline and travel lane data using a variety of sources including orthophoto digitizing, GPS data collection, and engineering drawings. These datasets are typically customized to meet local needs. They may be good for either geocoding or networking, but not both. Since they are supported locally, work with these providers to extend the capabilities of these datasets. To see several local datasets, check out the article, "[Do It Yourself—Building a network dataset from local agency data](#)" and "[Managing Volunteer Firefighter Response—Using the OD cost matrix to model personnel availability.](#)"

## Enhancing Street Data for Networks

Here comes the really important stuff! When you are sourcing (or have already obtained) a street dataset, what important network issues should you address? In a recent *ArcUser* article, "[Do It Yourself—Building a network dataset from local agency data](#)" (referenced above), I introduced several important issues you should consider when preparing a dataset for network modeling.



Here are key issues that can be tackled by spatial and attribute editing.

## Impedance—Distance

To properly calculate travel time, you need accurate distances. In a well-defined and documented model, distance-based impedance is easy to calculate. If your streets are registered in a standard projected coordinate system, you can readily calculate and verify distances between intersections in the native coordinates. If you are careful, you can calculate distance in a geographic data frame or across the metric/imperial measurement divide.

I use a field named Length\_Mi to store travel distance. Since this is not a reserved field name, you must specify this field and its units when you build a network. I do not use the field name Length, as I often store length in multiple units of measurements (both metric and imperial) and certainly do not want to confuse these systems. As you edit your network dataset, recalculate segment lengths frequently, especially before you rebuild a network.

## Impedance—Speed

A reliable time-based impedance (or speed) field is essential. Many agencies start with posted or ordinance speeds and factor them up or down, depending on policy, persistent

travel constraints (such as slope and turn radius), and variable travel factors (weather, traffic, and disruptions, to name a few). Measured travel times allow a user to fine-tune speed-based impedance. Once directionality and connectivity issues are resolved, the segment length in miles and travel time in minutes can be calculated. If you use a field named Minutes, Network Analyst will recognize it immediately. Remember to recalculate segment length, then travel times on all street segments (or at least the ones edited) each time you finalize an edit session and before you rebuild your network. Be sure to edit or remove all zero-time segments in the dataset before you rebuild.

## Crossing Relationships

Overpasses and intentionally nonconnecting crossings are two of the most difficult and important issues to address. Commercial streets use an integer code or Z elevation/Z level to manage crossing geometries. The Z elevation fields (from and to) specify whether traffic may turn at an endpoint intersection. To turn or traverse through an intersection, the endpoint of the traveled segment must match the start point of the new segment. Most simple networks will use only Z values of 0 and 1. However, a Los Angeles County commercial dataset that I recently modeled included Z elevation values up to 4. If you add new streets to a dataset that uses Z elevations, be sure to correctly populate this field.

A simpler way to manage crossing relationships, especially streets not also used for geocoding, is to build nonintersecting crossing geometries and apply endpoint connectivity. These streets are much easier to edit and visually inspect, and they perform much better if you are using lidar terrain to define slope impedance.

## Connectivity

Connectivity defines how an individual element in a network relates to its neighbors. Simple connectivity options include endpoint and any vertex. I strongly recommend that you use endpoint connections. See *Crossing Relationships*, in the previous section, for more information.

Simple single-layer networks must have exact endpoint connections to function properly. I find that nonconnecting segments are the most common issue that will cause a network to fail. Use visual inspection, polyline topology, editing, and/or old-fashioned trial and error to define, repair, and maintain connectivity.

If you use a multimodal network that includes several feature classes, connectivity between participants is defined with special rules. Remember that you must place all participating feature classes in a single feature dataset to build multimodal models.

## Directionality

Travel direction is critical when modeling one-way travel on divided highways, boulevards, one-way streets, and even individual travel lanes.

When streets are digitized, the digitizing direction creates an underlying street direction. To manage travel along or against this direction, a two-character text field named `One_Way` provides an effective way to flag travel direction relative to digitizing. Simple FT (from-to) and TF (to-from) codes define the course along and against the digitized direction. To check directionality against digitized direction, place small arrows at the terminating end of the street segment. Code a selected segment FT if travel is along the elements direction; use TF if travel opposes. In an edit session, also watch for the segment's red endpoint; it also represents the terminating end.

If your street network will not support address geocoding, you may also flip the street direction to reflect actual travel. Again, check out [“Do It Yourself—Building a network dataset from local agency data”](#) to learn this workflow. If you do use streets for geocoding, you may still reverse its direction, but you must reassign the left/right to/from values to respect the new orientation. This difficult task requires attention to detail, and I do not recommend it for beginners.

When you build a network dataset, Network Analyst will recognize the `One_Way` field and create the appropriate rules.

When using the network, you will have the option to globally turn the One Way property on or off.

## Turns and Turn Relationships

In a time-based network, turns and intersection slowdowns are very important. Global turns may be quickly applied throughout a network. As you build your network, use actual field times to calibrate them throughout your jurisdiction. You will probably find that travel times under constant low volume will vary slightly throughout your area. Experiment with global turns to achieve a best average. Field testing is described in "[Convincing the Chief—Proving that time-based networks really work](#)," an article that appeared in the Spring 2009 issue of *ArcUser* and that is also available from the [Network Modeling, Learn How to Model Networks Web page](#). These Hands On articles build skills.

If you want to model individual turn penalties for many or all intersections, you can create individual rules for all intersections. This is a complex procedure that I do not recommend for people who are new to working with networks.

- **Don't Give Up**

Stay with it. As you refine your network, you will be amazed with the possibilities. Building a reliable time-based network is not an easy task, and tuning and maintaining it are even tougher. Do not be discouraged. There are probably many potential partners in and around your jurisdiction that might

want to help. In addition to finding some help in creating and maintaining your network data, here are some strategies for making the job easier.

- **Start Small**

Build a small network in an area that you know well. Experiment and tune it to match field tests. Carefully watch how the network behaves as you build small service areas and test routes. If impedance, connectivity, geometry, and travel direction misbehave, practice fixing and rebuilding them. Test, and test, and test!

- **Think Big**

Ultimately, your network will probably support the response efforts of many jurisdictions. Talk to your neighboring jurisdictions and develop partnerships. Collectively decide to obtain/create and maintain just one network dataset.

- **Keep Both Eyes Wide Open**

Continually monitor your network's behavior. Repair problems individually or in small groups. Rebuild and retest problem areas. Do not be discouraged if fixing one problem just reveals another.

- **Document Your Work**

Develop a method to track edits and network builds, especially when adding new segments and modifying attributes. When you build the network for the first time, before you click the Finish button, save your parameter

summary to a text file with a date stamp. If you ever have to present and defend your work, you will be glad you did. I have presented network models to the legal community, and this information is priceless.

- **Back Up and Try Again**

Occasionally, a network dataset becomes quirky or even corrupt. Do not hesitate to delete the problem set and rebuild using the same parameters. If you use a standard naming convention, you might be able to reuse the same dataset in an existing ArcMap document. Be very careful with this, though. You might have to remove the repaired dataset from an existing ArcMap document and rebuild all the solvers. I have had mixed success with replaced datasets and consider the jury to still be out on this strategy.

(This [article](#) originally appeared in the Fall 2009 issue of *ArcUser*.)

# The Call Comes In

Quickly and accurately map emergency incidents with a composite address locator

By Mike Price, Entrada/San Juan, Inc.

Address geocoding is an essential public safety skill. However, officers need to understand the benefits, limitations, and complexities of systematic address locators. To quickly and accurately map incident locations, a Public Safety Access Point (PSAP) relies on computer-aided dispatch (CAD) software and georeferencing datasets to match the caller's address to a point on the map. At the dispatch center, a trained operator must capture, interpret, record, and map as much incident information as possible.

After determining the incident's location, the operator identifies the needed and available resources and passes as much information as possible to responding units. These tasks must be accomplished as quickly as possible—typically 60 seconds or less. Once mapped, the CAD system matches the closest available emergency resources with the call type and sends out automated tones, coupled with digital information and voice instructions. Consistent, complete, and current addressing datasets are essential to this process.

This exercise shows how to produce addressing datasets by creating geocoding services or address locators for three datasets that will place a location on a map with a high degree

of accuracy. Rather than geocoding a single incident, this exercise processes several thousand incident points captured during a single year in a major metropolitan area. Standardizing addresses and using a progressive composite address locator will achieve an extremely high success rate on the very first pass. This exercise applies the same sequential logic that is used by response centers around the world.

The data for this exercise was created for a textbook and tutorial series on performing emergency services mapping. It is based on data from actual jurisdictions and represents field conditions but has been modified to protect sensitive information.

The exercise is organized into five tasks:

## **Task 1: Understanding Addressing Data**

Obtain and analyze geocoding reference data. Review incident data format(s).

## **Task 2: Creating Individual Address Locators**

Design and build stand-alone address locators for each reference dataset.

### Task 3: Building a Composite Address Locator

Combine all address locators in hierarchical order in a composite address locator.

### Task 4: Geocoding Incidents

In ArcMap, geocode nearly 7,000 emergency incidents, updating unmatched addresses and resolving ties.

### Task 5: Adding Detailed Information about Incidents

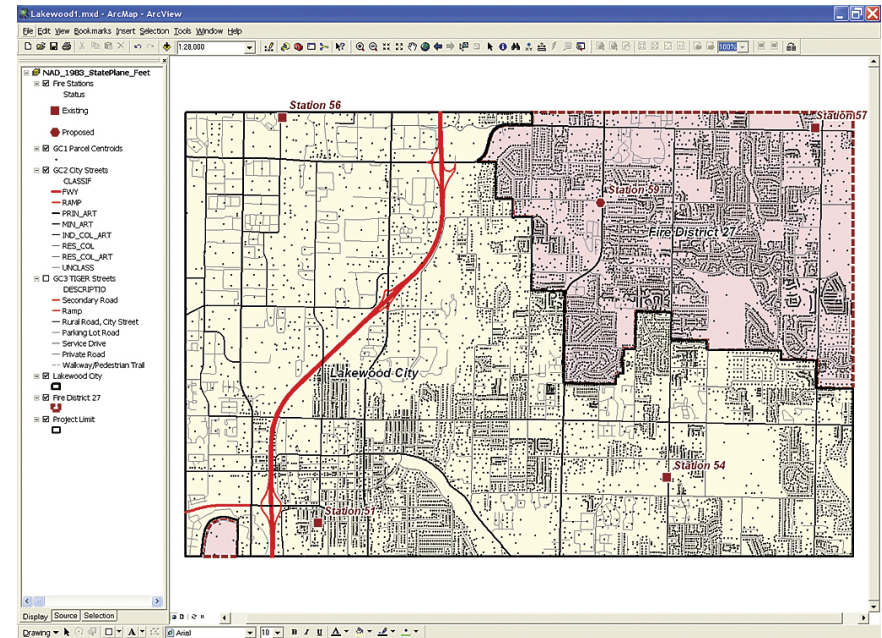
Join incident date and type information to all geocoded points to display fires and explosions, Hazmat incidents, emergency medical services (EMS) responses, and service calls.

#### What You Will Need

- ArcGIS Desktop 9.3 (ArcView, ArcEditor, or ArcInfo)
- [Sample dataset](#) [ZIP] downloaded

## Getting Started

To get started, [download Lakewood.zip](#) [ZIP]. Store this file near a root directory and extract the data, respecting directory structure. Start ArcMap, navigate to the new Lakewood folder, and open Lakewood1. Right-click in an open toolbar area and select the Geocoding toolbar. Move it next to the other open toolbars and inspect its buttons. The Address Locator Manager



The exercise data is based on data from actual jurisdictions and represents field conditions but has been modified to protect sensitive information.

and Geocode Addresses buttons are active. Two other tools, Location Inspector and Review/Rematch Addresses, are inactive.

## Task 1: Understanding Addressing Data

A typical PSAP will use several address datasets to place an incident on a map. A geocoding sequence starts with the most reliable, accurate, and current dataset available to identify a single point location on a map. To increase the success rate of the geocoding process, the service will standardize incoming



addresses to match the reference data schema. Place-name alias tables also increase geocoding reliability.

1. Open the attribute table for GC1 Parcel Centroids and inspect its fields. Study the SITE\_FULL field and sort it. Notice that each address includes one standardized string, possibly including an address numeric; a direction prefix, a street name, a street type, and a direction suffix. These address points provide a certain address match against standardized input data with a high degree of reliability.
2. Open the attribute table for GC2 City Streets and inspect its fields. This dataset, developed and maintained by the Lakewood Public Works Department, is current and complete. This polyline dataset separates addressing into left and right and to and from numerics, and includes separate fields for name direction and type. GC2 City Streets is the second geocoding data source. It supports a U.S. Streets Locator. Unfortunately, CAD data often does not include sufficient information to apply a U.S. Streets with Zone Locator. Typically this data lacks municipality or ZIP Code information. Each agency must decide how to clip streets to include unique names or process addresses in different communities that share similar street names.
3. Next, open the attribute table for the GC3 TIGER Street shapefile and inspect its fields. This dataset is adapted from 2009 Census TIGER street data, now in development by

the U.S. Census Bureau. It includes a schema similar to the Lakewood Public Works data. Notice that field names and placement are different. This is the third addressing dataset, and it captures many road intersection addresses and the locations of incidents that might occur outside the extent of the Public Works dataset. The TIGER 2010 data, not yet released, will be different from TIGER 2000 data.

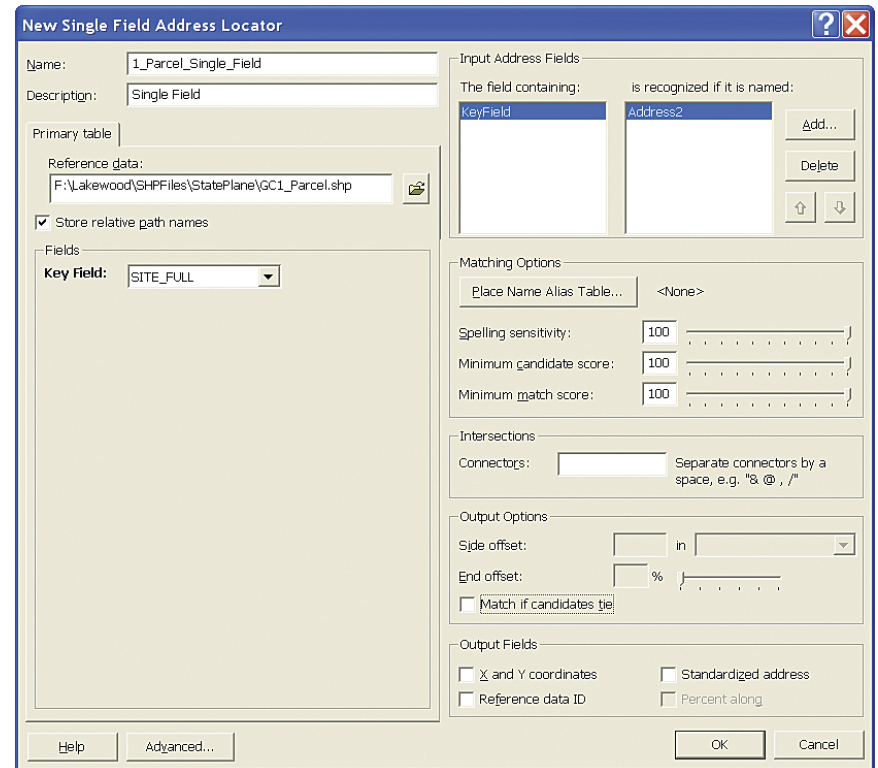
4. Now click the Add Data button, navigate to \Lakewood\DBFFiles and locate Inc\_2008\_Address, and load this table containing incident data. Open this table and inspect it. This dataset contains nearly 7,000 incident records and has only a few fields. It has an index field (INDEX), an incident number field stored as an alpha string (INC\_NO), and a standardized address field named ADDRESS2. Notice that there is no field in this dataset to identify a geocoding zone.
5. Sort ADDRESS2 and notice it contains both numeric and street intersection addresses. These addresses were generated and posted using CAD software, then edited by the local jurisdiction to correct inconsistencies. This data is clean and contains only incident addresses. Other information will be joined to these geocoded points later using the INC\_NO field.

*To review: In this task, the three reference datasets in the map document were reviewed, and one file containing incident data was added to the map document.*

## Task 2: Creating Individual Address Locators

Address locators will be created for each reference dataset in this task.

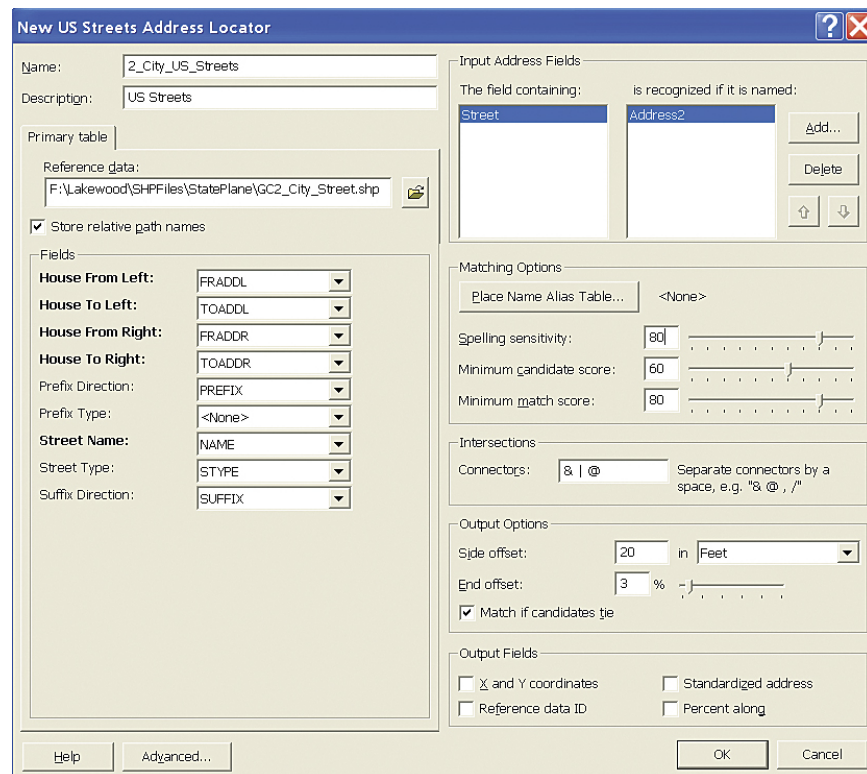
1. Save the ArcMap document, close ArcMap, and start ArcCatalog. Navigate to \Lakewood\SHPPFiles\StatePlane and preview the tables and geography for the shapefiles. The file name for each reference file begins with the letters GC and a numeric code that indicates that file's geocoding sequence.
2. In the ArcCatalog tree, right-click the \Lakewood\SHPPFiles\StatePlane folder and select New > Address Locator. Specify Single Field as the Address Locator Style and click OK.
3. In the New Single Field Address Locator dialog box, enter 1\_Parcel\_Single\_Field as the Address Locator name. On the Primary table tab, set Reference data to \GC1\_Parcel.shp and set SITE\_FULL as the Key Field. In the Input Address Fields area, delete Name from the field under is recognized if it is named and add Address2. Set all scores and sensitivities to 100.



Create a Single Field Address Locator that references the GC1\_Parcel shapefile.

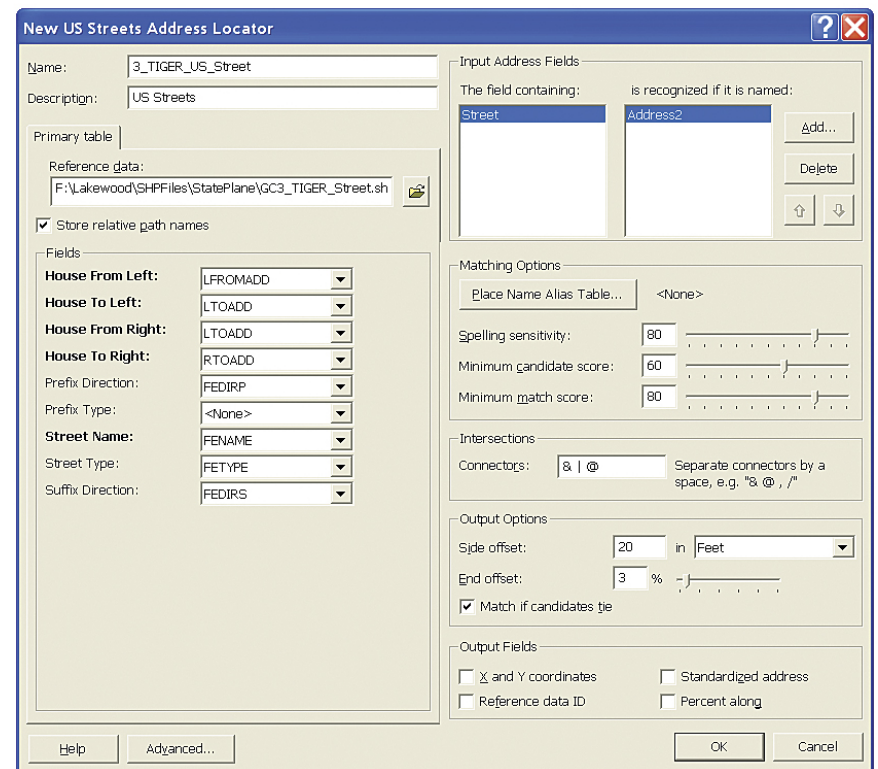
4. **Under Output options, uncheck the box next to Match if candidates tie.** It is essential to uncheck this box because all ties (based on duplicate addresses) will be bumped to the City Streets locator. Click OK to build the 1\_Parcel\_Single\_Field locator.

- Build the 2\_City\_US\_Streets geocoding service by right-clicking the \Lakewood\SHPPFiles\StatePlane folder and creating a second address locator. Use Tables 1 and 2 as guides when creating this locator. Name this address locator 2\_City\_US\_Streets. Set \GC2\_City\_Street.shp as the reference set, and define reference fields using the same parameters as



The second geocoding data source, GC2 City Streets, supports a U.S. Streets Locator. It is maintained by the Lakewood Public Works Department and is current and complete. It will be used to build the 2\_City\_US\_Streets address locator.

- 1\_Parcel\_Single\_Field locator. This time, using the information in [Table 1](#) [PDF], specify fields for numerics, direction, and type. Although many addresses will automatically match, don't forget to make sure STYPE is chosen for the Street Type field. If a required field is accidentally omitted when creating a locator, delete the locator and rebuild it. Set only Address2 as



The data source for the third address locator, the GC3 TIGER Street shapefile, was adapted from 2009 Census TIGER street data, now in development by the U.S. Census Bureau.

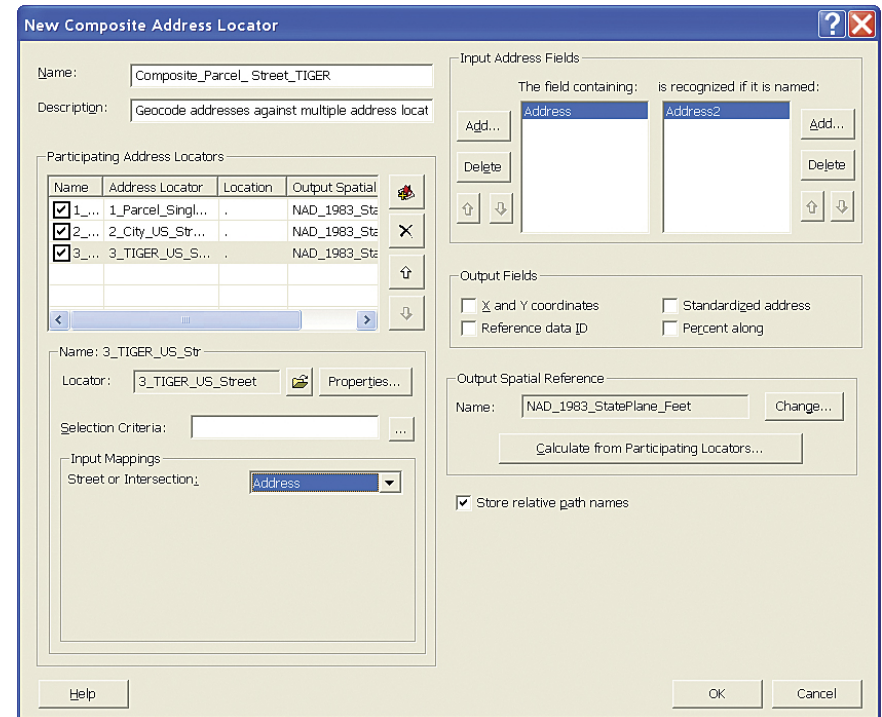
the recognized field and set spelling and scores to 80, 60, and 80. Accept the Connectors defaults and leave other choices unchanged. Click OK to build this locator.

- Next, build the 3\_TIGER\_US\_Street geocoding service using parameters in [Tables 1 and 2](#). This locator is similar to the 2\_City\_US\_Streets locator. Because the new TIGER codes are not consistent with earlier systems, the field names will not assign automatically, so carefully assign fields as shown in [Table 2](#) [PDF].

### Task 3: Building a Composite Address Locator

The three individual address locators just created are now linked together in a composite address locator. A composite locator links two or more other address locators together in a hierarchical order and passes unmatched addresses from each locator to the next. This composite address locator will geocode using Parcel Centroids first, then City Streets, and finally TIGER Streets.

- Right-click the \Lakewood\SHPFFiles\StatePlane folder and specify Composite Address Locator.
- Using [Table 3](#) [PDF], name this locator Composite\_Parcel\_Street\_TIGER and add participating locators in order: 1\_, 2\_, and 3\_. These numeric name prefixes will be useful soon.



Use the three individual address locators to create a composite address locator.

- Once all three are loaded, perform the next step. It is a performance tip. On the right side of the New Composite Address Locator wizard, find the Input Address Fields area. Next to The field containing window, click the Add button and specify Address as the primary field. Set its recognized name to only Address2. By specifying only Address2, the composite address locator will target only standardized data and ignore



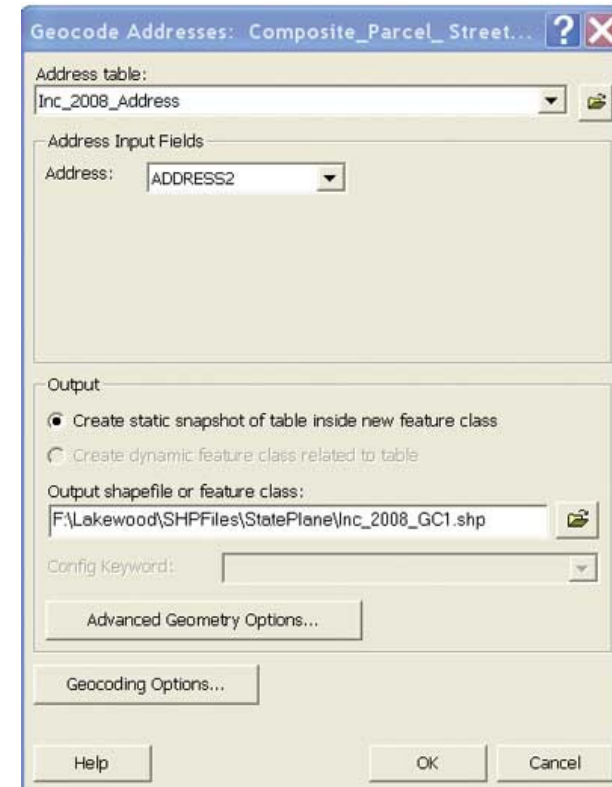
other Address fields. Typically reference datasets can also contain a primitive Address field.

4. Keep all Participating Address Locators checked; select each one and individually set its Input Mappings field to Address. Use any individual address locator to calculate the output spatial reference. After setting the spatial reference and all three Input Mappings, the OK button should become active. If it does not, review the setting. Click OK to build the composite address locator. Now it is time to geocode all 6,976 incidents. Close ArcCatalog and reopen the Lakewood map document in ArcMap.

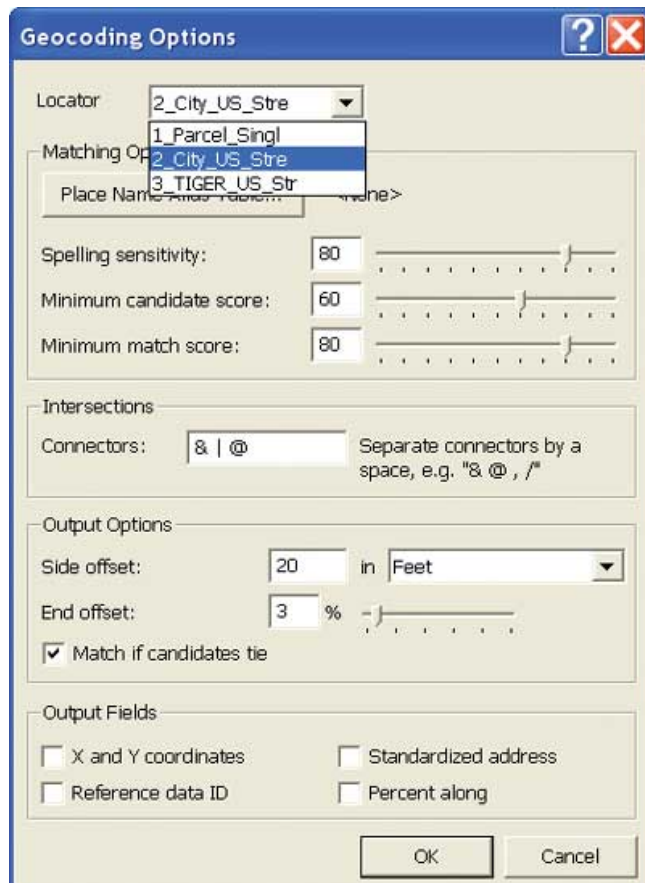
#### Task 4: Geocoding Incidents

Now, after setting some parameters for the composite address locator, it will automatically geocode all the incidents.

1. In ArcMap, load the Geocoding toolbar, if necessary, and click the Address Locator Manager button. Navigate to \Lakewood\SHPPFiles\StatePlane and load only Composite \_Parcel\_Street\_ TIGER. Close the Locator Manager window.
2. Open the TOC Source tab, right-click the Inc\_2008\_Address table, and select Geocode Addresses.



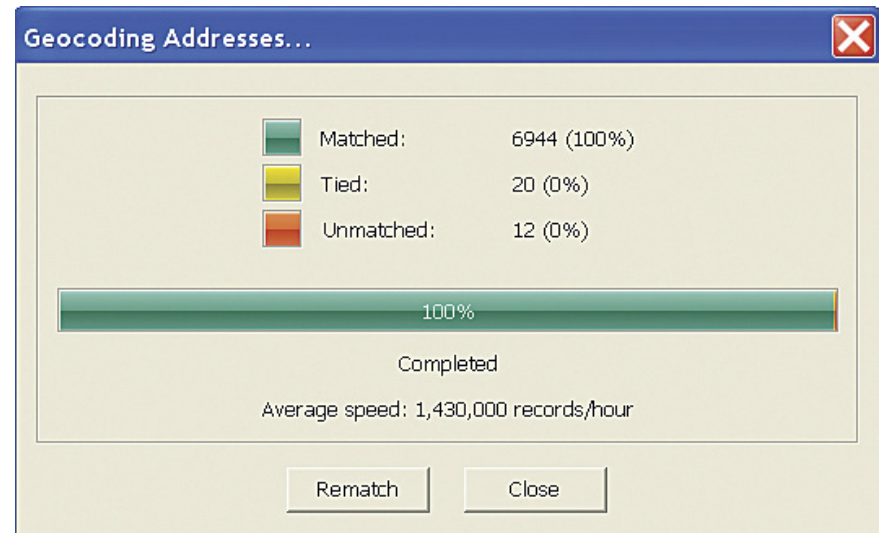
3. Set the output file location and name to \Lakewood\SHPPFiles\StatePlane\Inc\_2008\_GC1. Using a numeric counter in the file name will make it easier to rerun the model or test it with differing parameters. Click the Geocoding Options button to verify that all three individual locators participate in the composite address locator. Update or adjust properties, such as spelling sensitivities and threshold scores, at the same time if necessary. Click OK to continue and watch the geocoding process.



Keep all Participating Address Locators checked and select each one and individually set its Input Mappings field to ADDRESS2.

4. If the three address locators were built according to the specifications given, they should generate a high percentage

of matches. Only about 20 ties and 12 unmatched addresses should be left from the set of 6,976 incidents.



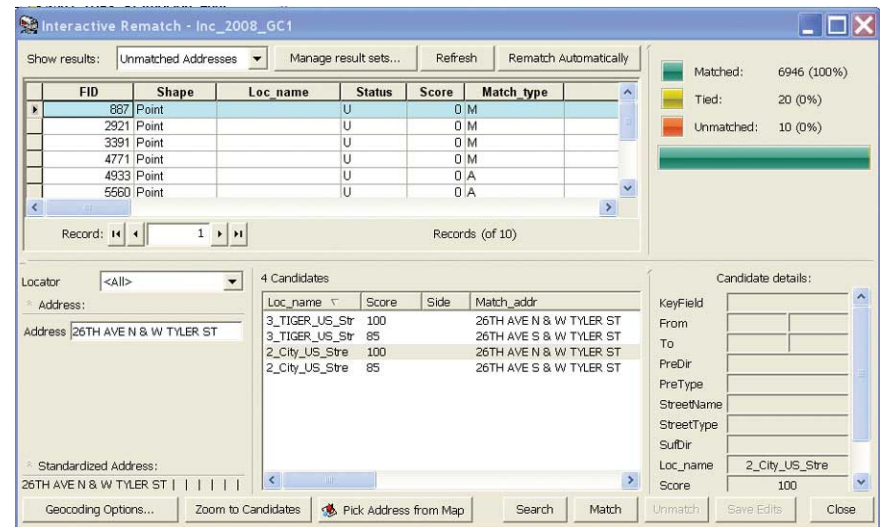
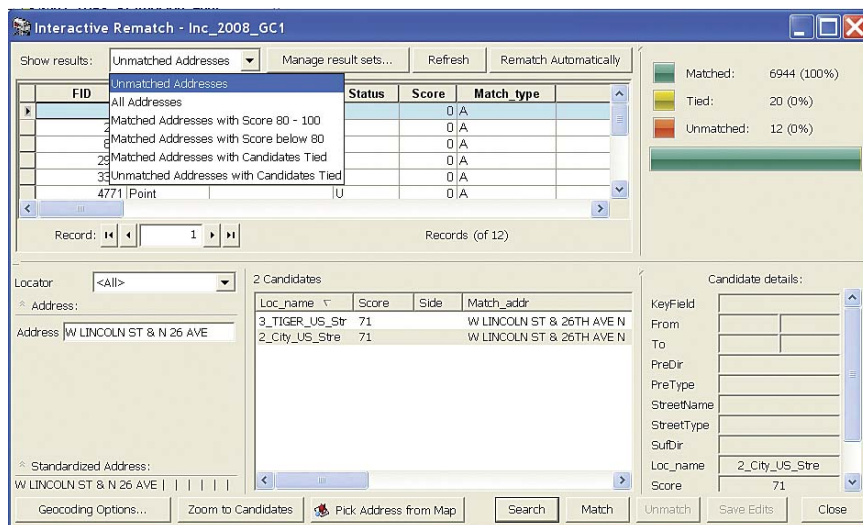
The composite address locator should generate 20 ties and 12 unmatched addresses.

5. The sample dataset includes a Microsoft Excel spreadsheet containing suggested fixes for known addressing errors. Navigate to \Lakewood\Utility and load the Database worksheet, Fixes1.xls. Review its contents. In the real world, records management at a fire station is never perfect, and this spreadsheet contains fixes for several nongeocoded records.



- To update these unmatched or tied records, click the Rematch button. Let's repair unmatched addresses. Under Interactive Rematch, look at the Show results area and select Unmatched Addresses. In the results window, locate an improperly geocoded address and find its corresponding entry in the Fixes1 table. Copy the ADDRESS2\_F string into the text box next to Address on the left side of the Interactive Rematch dialog box. Click the address in the Candidates list and select the record with the highest percentage (which will likely be the one with the highest order, e.g., 1\_, 2\_, or 3\_) and click Match. The score will change from U to M, and the Loc\_name field now lists reference data, providing the best fit. Continue down the list, making repairs, selecting the best reference

data and building matches. When finished, all records should match.



Use the Fixes1 table to fix unmatched addresses by copying the ADDRESS2\_F string into the text box next to Address on the left side of the Interactive Rematch dialog box.

- Review tied records next. In Show results, select Matched Addresses with Candidates Tied. Locate the ADDRESS2 window and sort its contents so identical tied addresses are grouped. Ties often occur in clusters, so fixing one will often fix others.
- Click one of the candidates in the window. The selected record is displayed as a larger yellow dot on the map. Below the Candidates window, click the Zoom to Candidates button.

Click the Rematch button and under Interactive Rematch, select Unmatched Addresses.

If you could access the actual incident records, you could select the appropriate point. However, that is not the case in this exercise, so select the westernmost or northernmost point (as long as these points are in close proximity—say, 1,000 feet or less). Click the Pick Address from Map button and use the crosshair tool to choose the best candidate, then click Match. Also check the Fixes1 spreadsheet to see if any ties show up there.

After matching the last tied records, all tied records should show a 100 percent score. While matching ties, look for the reasons they occurred. Some are readily fixed by editing street address ranges, which will require that you rebuild the affected address locators before continuing. Other errors, such as those caused by looped streets and offset intersections, are hard to avoid.

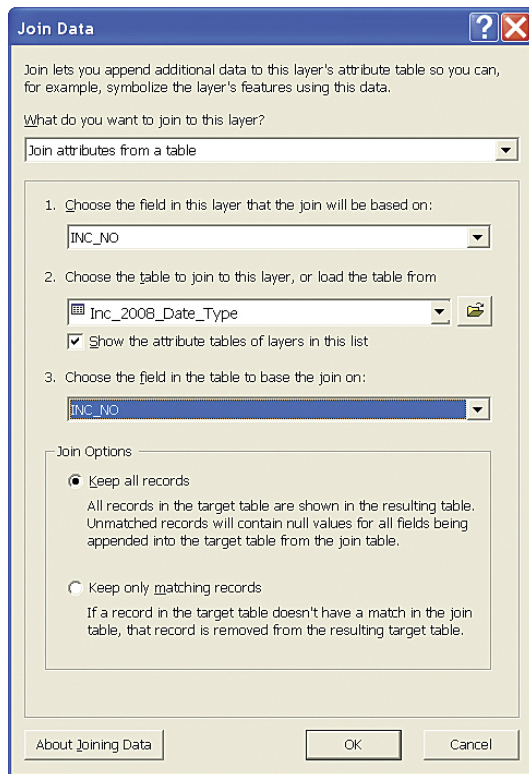
Finally, consider matched addresses that score less than 100. Show results for matched addresses and sort the Score field in ascending order. Only a few records will have scores less than 100. See if you can boost those scores to 100 by using observations, intuition, and the Fixes1 spreadsheet. After fixing all records, close the Interactive Rematch dialog box and save the map document.

## Task 5: Adding Detailed Information about Incidents

The input data contains only incident numbers and addresses. With all these points properly placed on a map, joining or relating data from other tables will add more information on the incidents such as date and type of incident. The last step will symbolize incidents using a graduated color scheme that identifies incidents by type.

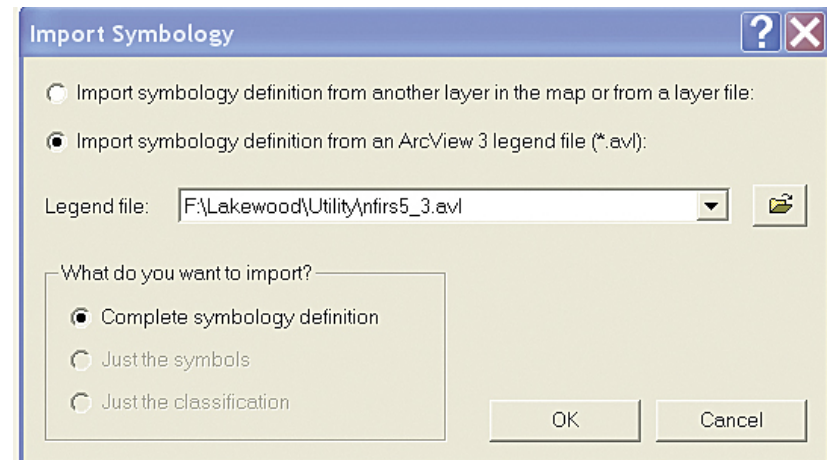
1. Navigate to \Lakewood\DBFFiles and add Inc\_2008\_Date\_Type.dbf to the map document. Open Inc\_2008\_Date\_Type and compare it to the attribute table for Geocoding Results: Inc\_2008\_GC1. Note that these tables share a common field, INC\_NO, so there may be a one-to-one relationship between the tables.

2. Right-click Geocoding Results: Inc\_2008\_GC1 and choose Join. Create this join to Inc\_2008\_Date\_Type.dbf using INC\_NO as the common field. Inspect the results and verify that all records have joined.

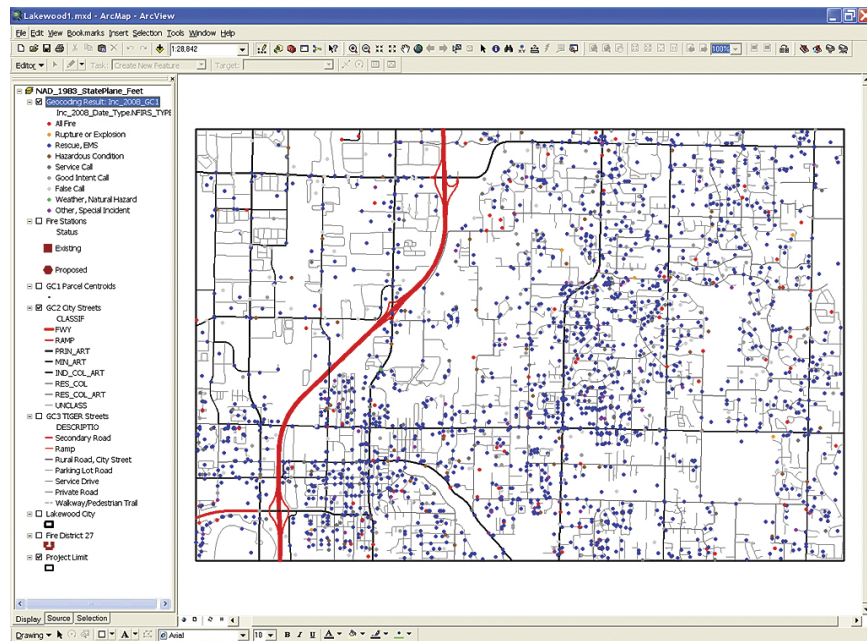


Join the table Inc\_2008\_Date\_Type to Geocoding Results: Inc\_2008\_GC1 to symbolize the incidents.

3. The next step symbolizes incident points using a graduated color legend that corresponds to the National Fire Incident Reporting System (NFIRS). Open the Layer Properties dialog box for the incident layer (Geocoding Results: Inc\_2008\_GC1) and click the Symbology tab. Click the Import button and choose ArcView 3 (\*.avl) file and navigate to the \Lakewood \Utility folder. Select nfirs5\_3.avl and set the Value field to NFIRS\_TYPE. Click OK several times to apply the legend.



Load the ArcView 3.x legend to use the NFIRS color scheme.



## Acknowledgments

The author thanks all the people who helped provide mapping data and other information that was used in this tutorial. Because this data has been synthesized, those providers might not recognize their own data. Thanks also go to the author's advanced GIS students at Bellingham Technical College in Washington who helped identify and resolve real-world training issues.

(This [article](#) originally appeared in the Spring 2010 issue of ArcUser.)

Once the incidents are symbolized, check the symbology properties to learn more about the incidents.

4. Save the finished project. Once the color scheme is applied, check the symbology properties to learn more about NFIRS incident types. Incidents are coded thus: 100 series points are fire related; 200 series points are explosions or ruptures; 300 series points are rescues and EMS calls; 400 series points are hazardous conditions; and all points over 499 are service calls, false alarms, and special calls.





Esri inspires and enables people to positively impact their future through a deeper, geographic understanding of the changing world around them.

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