Do It Yourself!

Building a network dataset from local agency data

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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.

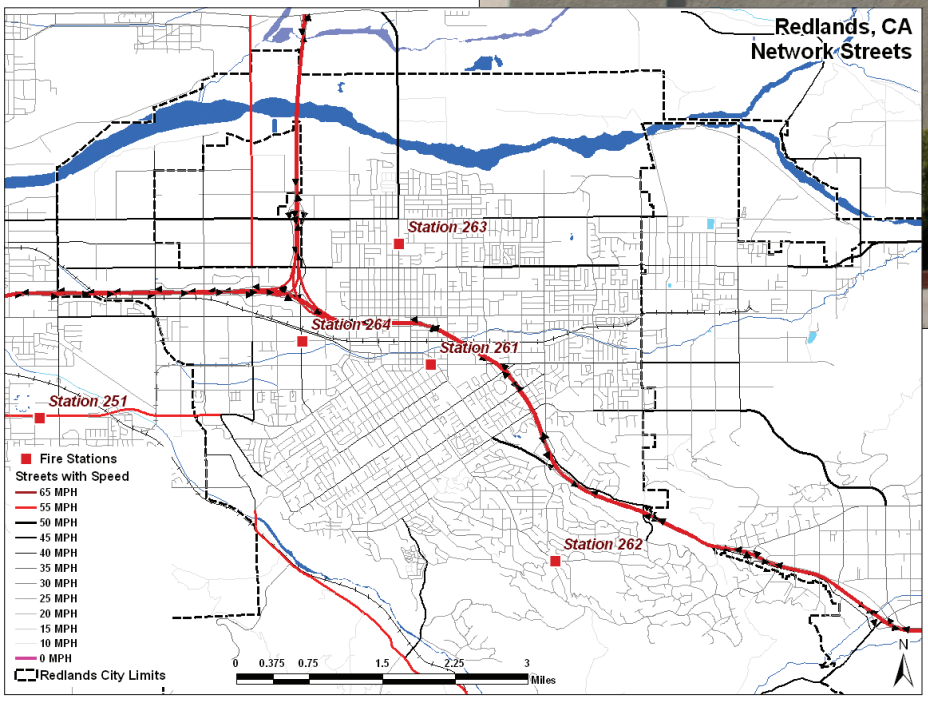
This article assumes a basic understanding of ArcGIS Desktop and the ArcGIS Network Analyst extension. To review modeling travel networks with ArcGIS Network Analyst and the concepts of distribution and concentration, please read and work the exercises published in the July–September 2007, October–December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

Getting Starting

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

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

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



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

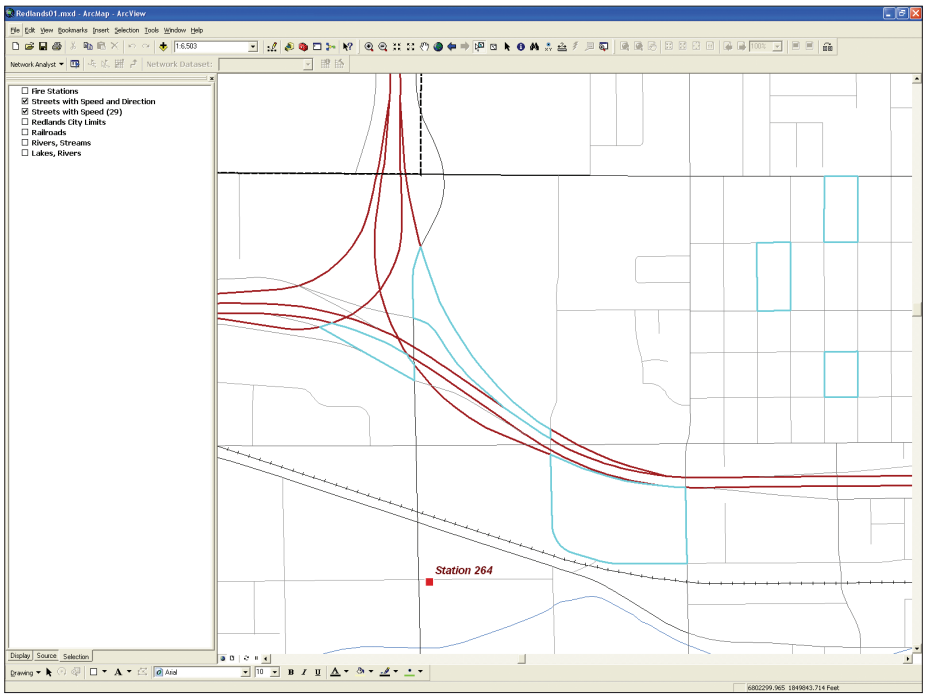
Adding Fields for Results

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

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

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

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



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

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

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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

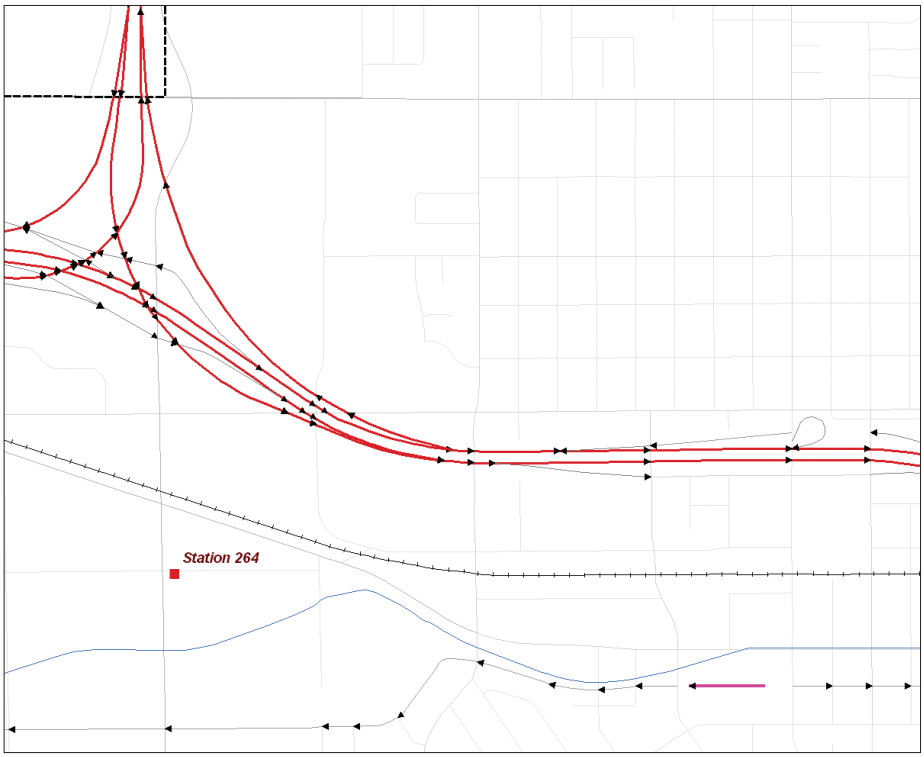
Because this is a geocoding dataset, it does not contain fields for nonintersecting crossings (which are also called z-elevations). Although two z-elevation fields could be added to this table, it would require careful editing of all the values for each crossing and intersecting street segment—a complex,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

Connectivity

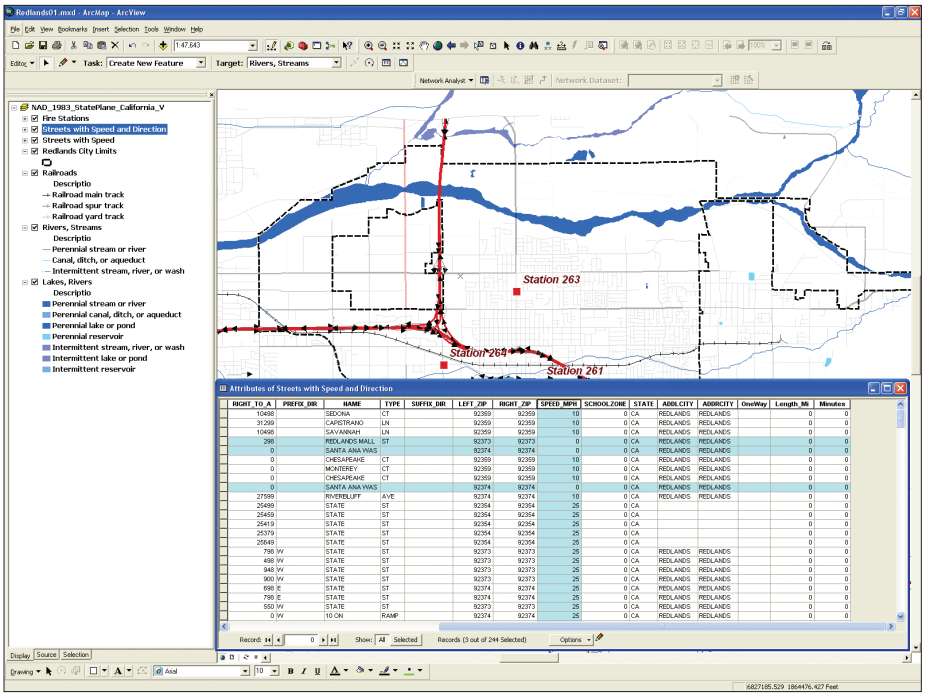
To properly create a network, all street segments must share common endpoints. Make the Streets with Speed layer selectable and zoom in or use the Magnifier Window to inspect intersections. Select street segments to verify connectivity. Notice that even freeway interchanges display connectivity where 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 interchange. Study the endpoint arrows and notice that not all segments are properly oriented for right-hand travel. This must be fixed. The OneWay field will be used to code all one-way segments.



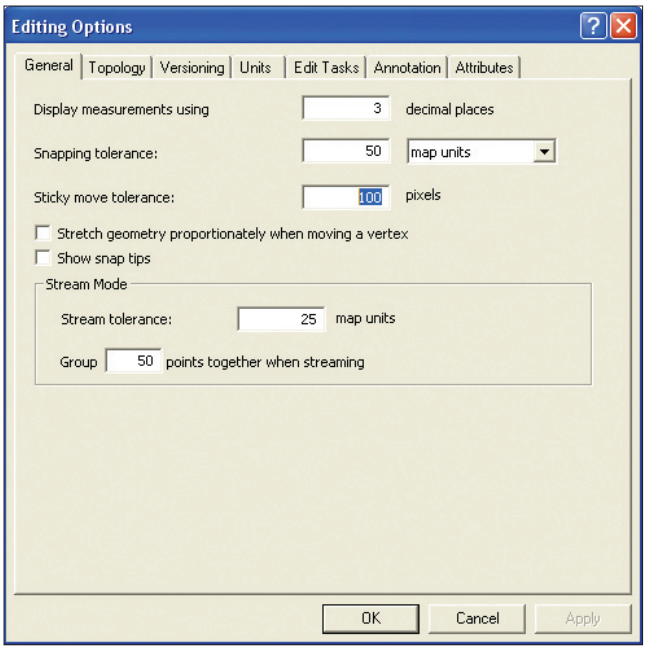
Study the endpoint arrows and notice that some segments are properly oriented for right-hand travel, while some are not.



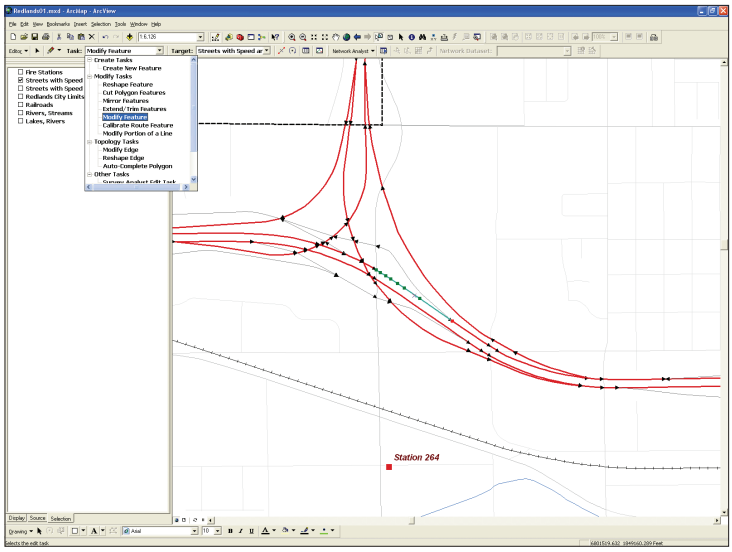
Delete Redlands Mall and the Santa Ana Wash; set all other speeds to 10 mph.

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.



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



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

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.

Directionality

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

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

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

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

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

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

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

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

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

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

Crossing Relationships

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

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

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

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

In the interchange area, study these crossing relationships carefully. Using the

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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.

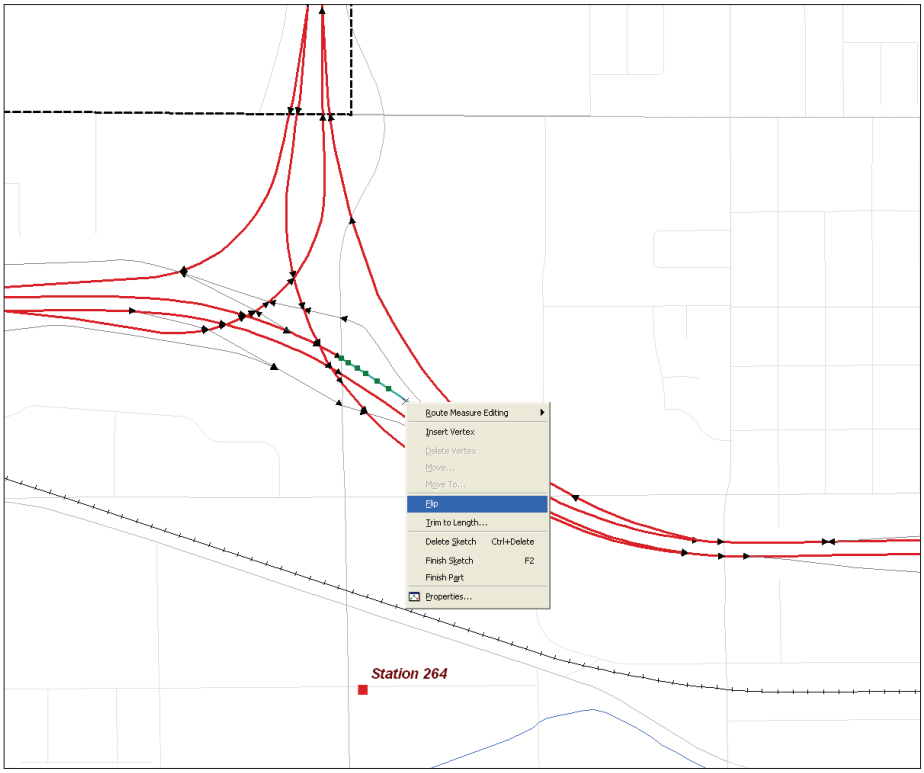
When all crossing freeway and ramp segments in the I-10/I-210 interchange have been merged to form single crossing elements, follow the rest of I-10 and I-210 and merge all these segments also to create single crossing elements. Watch the directional arrow and the red endpoint symbol while merging segments. 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.

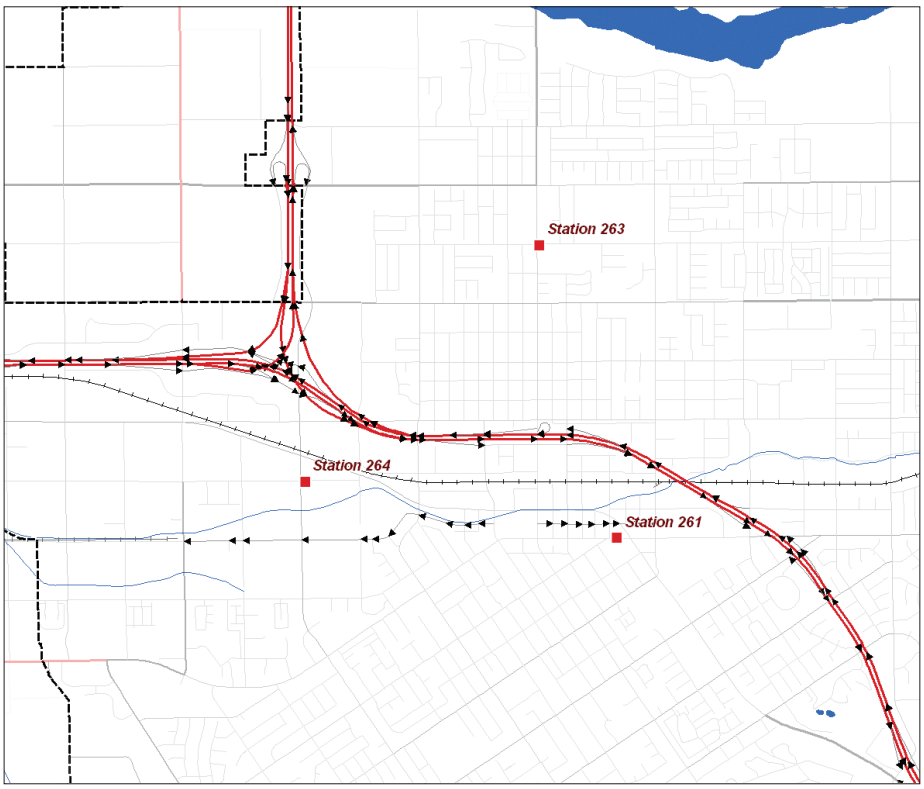
After completing all merging operations, inspect all freeway lands and ramps. Several ramps are problematic. It is difficult to tell if the feature being merged is part of an interchange or part of a crossing relationship. (Imagine how helpful high-resolution imagery would be.) When finished, stop editing,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

Editing Attributes

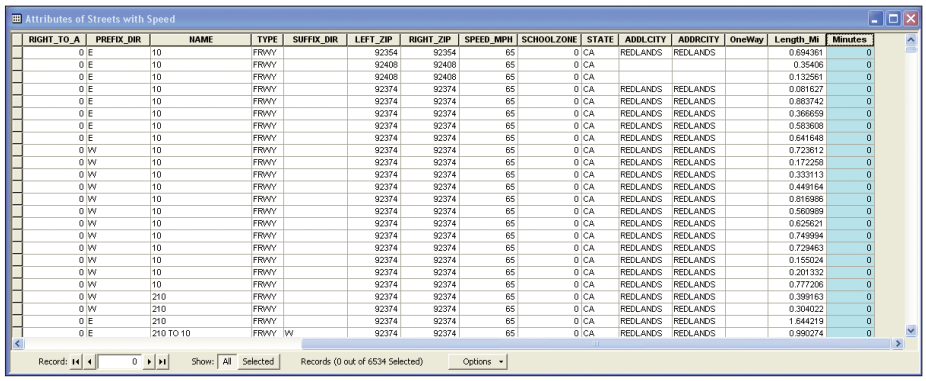
Now segment lengths and travel times can be calculated and directionality codes assigned to the OneWay field.



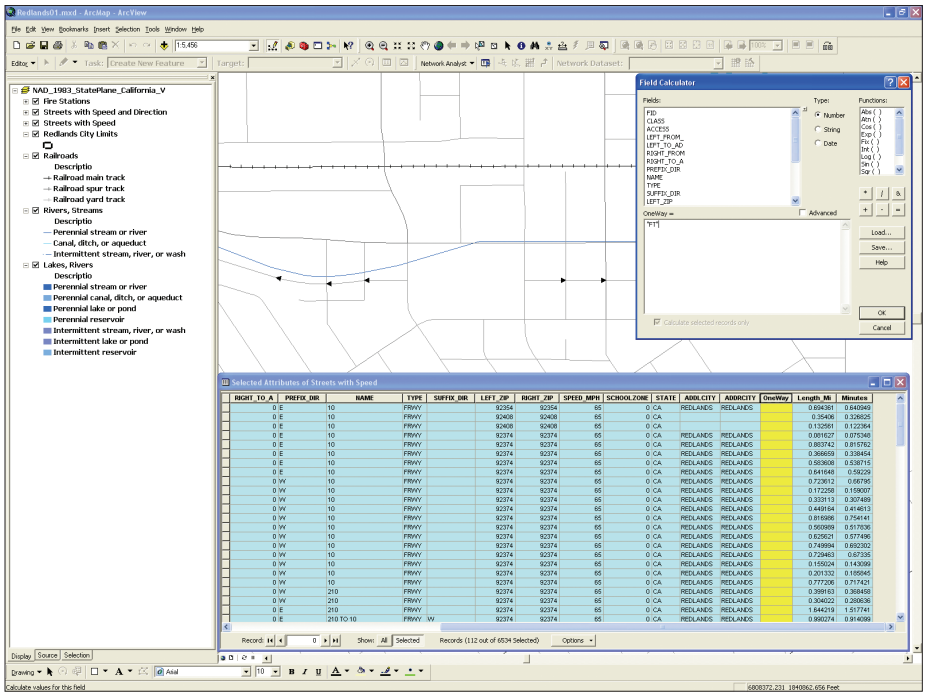
Carefully position the mouse cursor tip near the line's midpoint. (Hint: Look for the small x.*) Right-click and select Flip from the context menu. Watch as the red leading node swaps ends, indicating that the line has reversed direction.*



A properly oriented network



*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.*



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.

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

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

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

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

[Length_Mi] * (60/ [SPEED_MPH])

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

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

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

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

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

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

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.