Where are the best stops and routes for a bookmobile?

Case Study Workflow using ArcGIS Pro

This workflow provides the steps necessary to complete the spatial analysis presented in the hypothetical case study "Where are the best stops and routes for a bookmobile?"

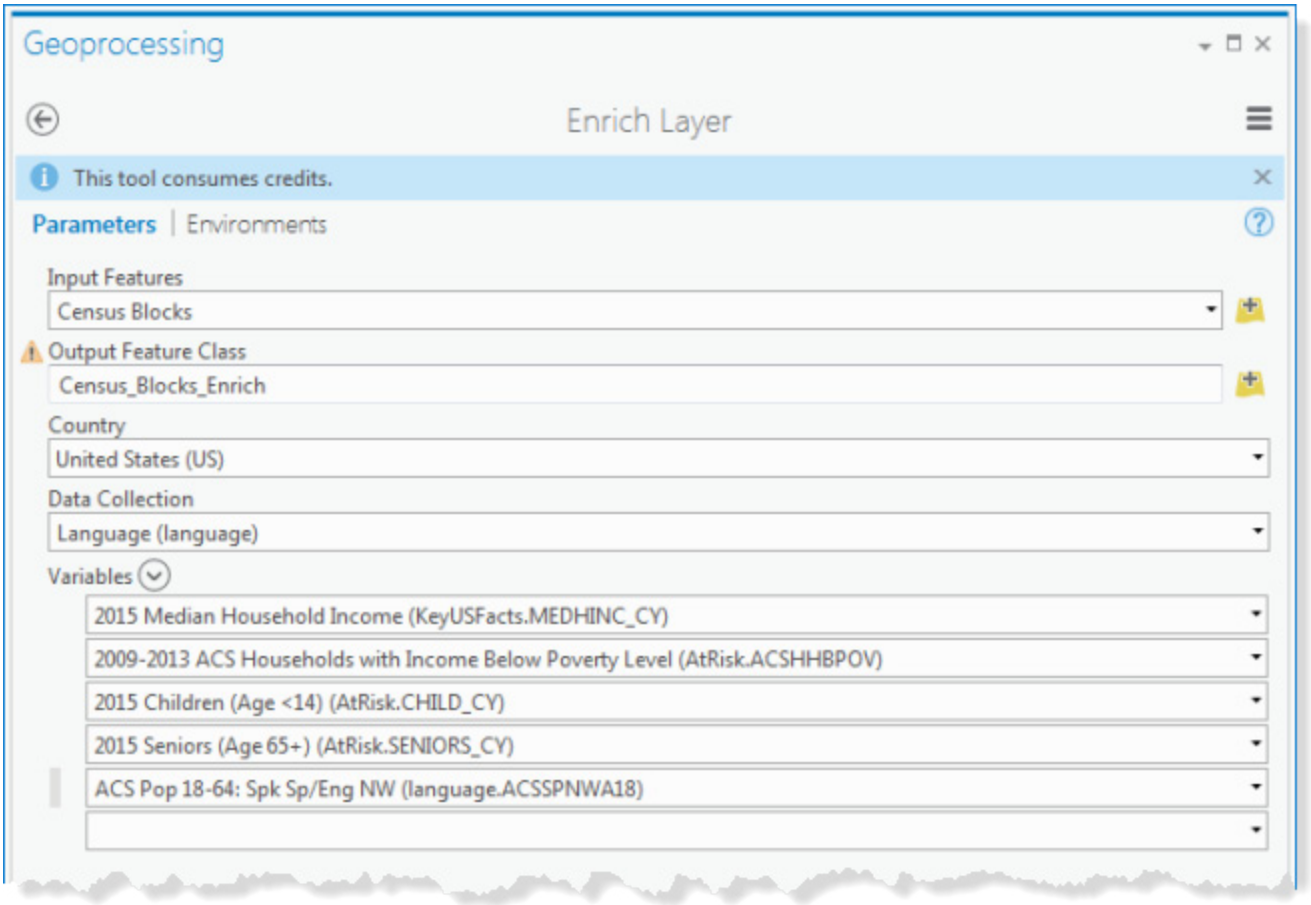
Case Study Section: Communities in need of books

- **Add the demographic data to the census blocks**
- **Create the map of median household income**
- **Create the hot spot maps**

Add the demographic data to the census blocks

Use Enrich Layer (on the Analysis tab) to add the necessary demographic variables to the census blocks. Learn about Enrich Layer. After specifying the input and output features and the country (United States), use the Data Collection and Variables dropdown menus to select the following variables:

- From the Key US Facts data collection select Median Household Income
- From the At Risk data collection select:
  - ACS Households with Income Below Poverty Level
  - Children (Age <14)
  - Seniors (Age 65+)
- From the Language data collection select Pop 18-64: Spk Sp/Eng NW



Here is the resulting attribute table for the Census Blocks layer.

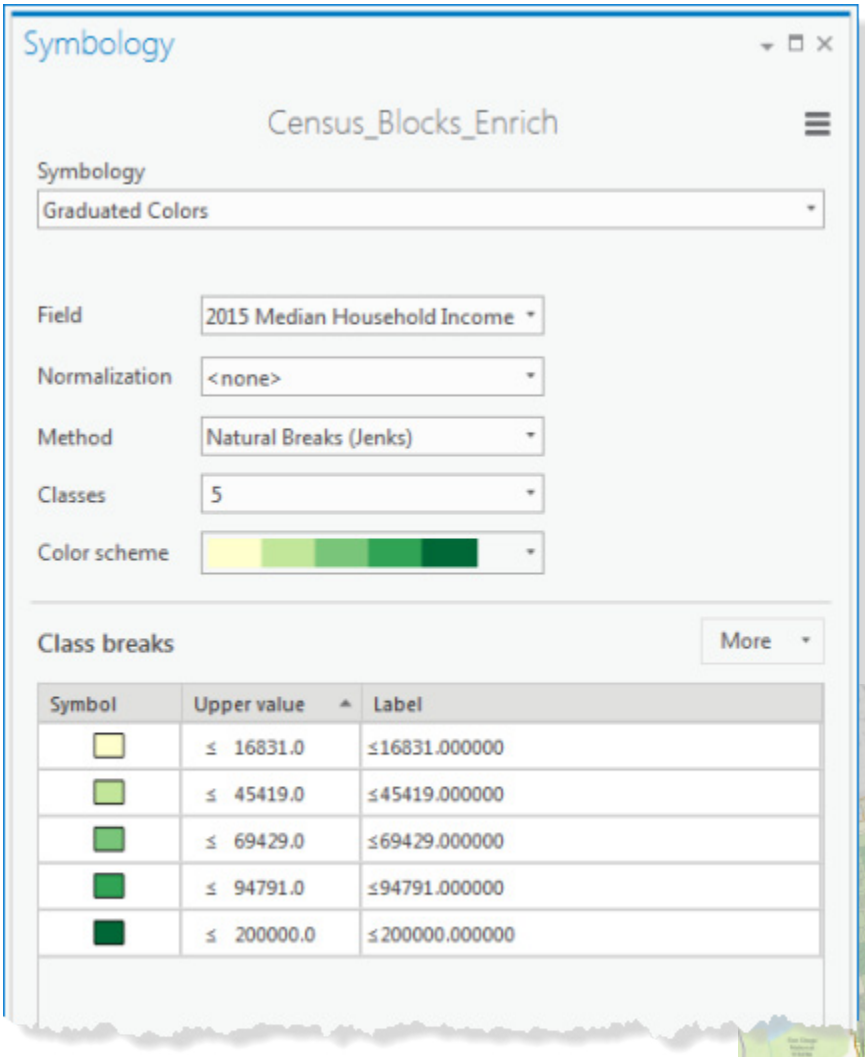
Census_Blocks_Enrich

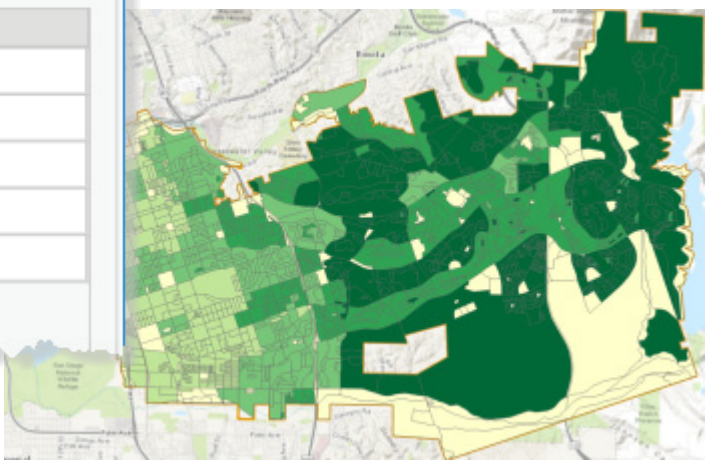
Field: New Delete Calculate | Selection: Zoom To Switch Clear Delete

OBJECTID	BLOCK	TRACT	2015 Median Household Income	2009-2013 ACS Households with Income Below Poverty Level	2015 Children (Age <14)	2015 Seniors (Age 65+)	ACS Pop 18-64: Spk Sp/Eng NW
1	1000	100.139999	0	0	0	0	0
2	1000	101.029999	42500	1	0	0	0
3	1000	101.07	0	0	0	0	0
4	1000	123.029999	0	0	0	0	0
5	1000	124.010002	0	0	0	0	0
6	1000	125.010002	16831	252	128	313	99
7	1000	125.019997	0	0	0	0	0
8	1000	127	27370	94	161	99	47
9	1000	128	75000	0	10	11	5
10	1000	131.020004	36259	0	63	46	9

Create the map of median household income

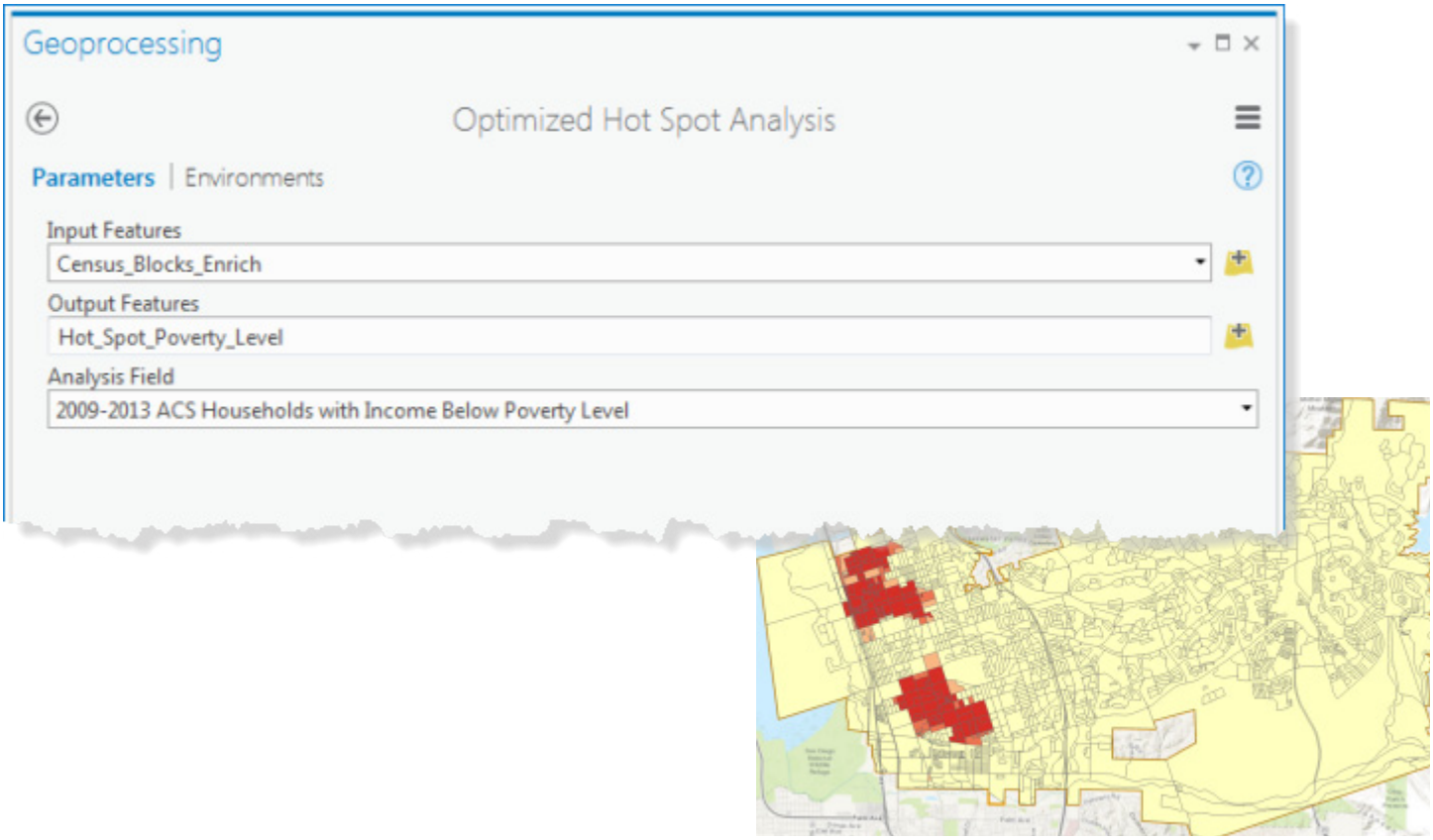
To create the map of census blocks by median household income change the symbology of the Census_Blocks_Enrich layer. Specify Graduated Colors for the symbology type, and Median Household Income as the Field. Use the defaults of Natural Breaks (Jenks) with 5 classes. Change the color scheme if you wish. Learn about symbolizing a layer.





Create the hot spot maps

Use the Optimized Hot Spot Analysis tool (on the Analysis tab) to create the hot spot maps for each of the variables in turn. Learn about Optimized Hot Spot Analysis. For households with income below the poverty level, specify Census_Blocks_Enrich as the Input Features, name the Output Features Hot_Spot_Poverty_Level, and specify the Analysis Field.



Now run the Optimized Hot Spot Analysis tool for the three other variables, specifying a unique name and the appropriate Analysis Field each time.

- Kids (Age < 14)
- Seniors (Age 65+)
- Adults (Age 18 – 64) Speaking Spanish, with limited English

Case Study Section: Finding the best stops

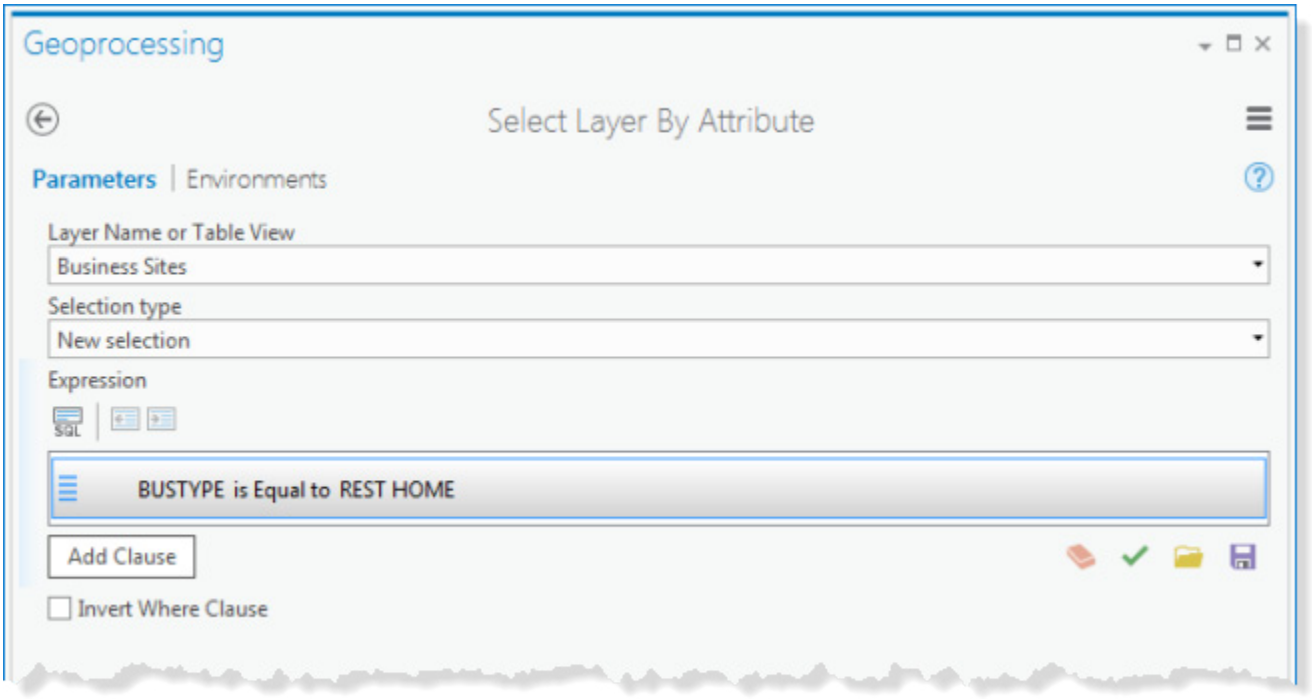
- Find the optimal senior facility stops
- Find the optimal retail center stops

Find the optimal senior facility stops

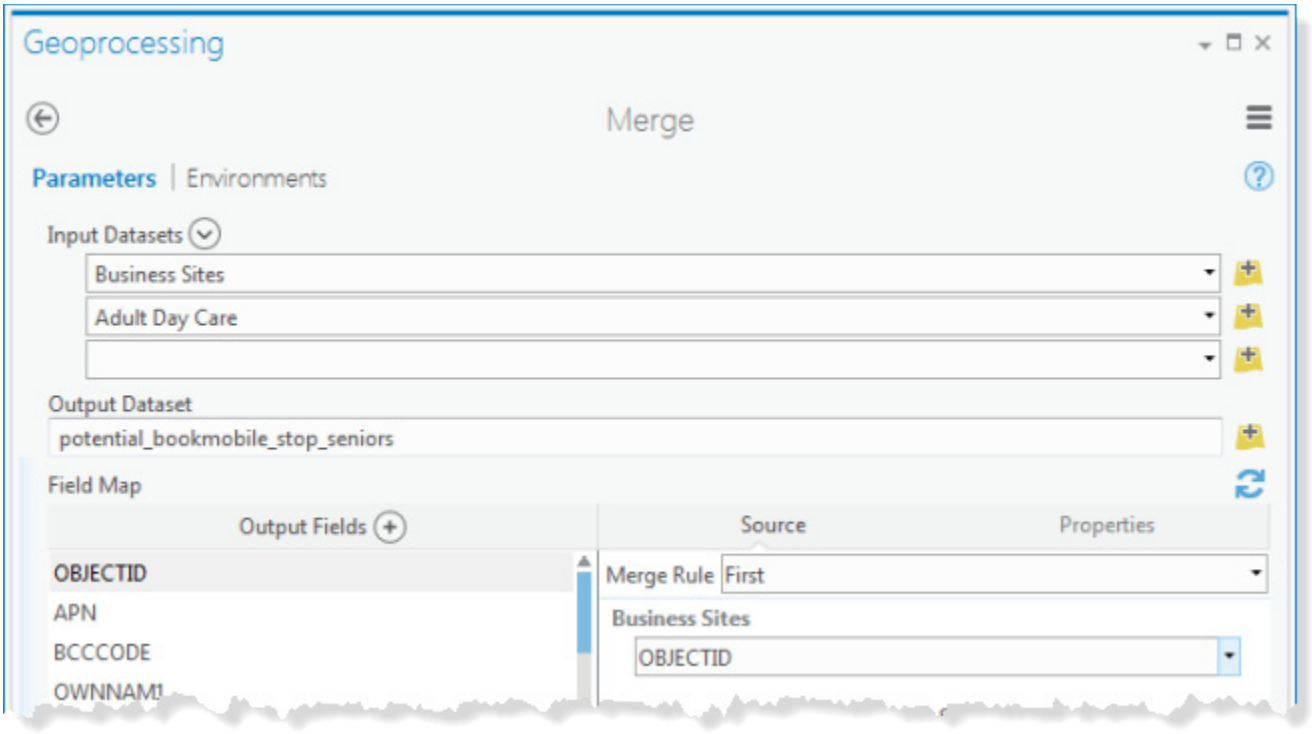
Finding the optimal senior facility stops involves several steps: creating the facilities layer, assigning a unique identifier to the facilities, creating the demand locations layer, and running the Location-Allocation analysis.

Create the facilities layer

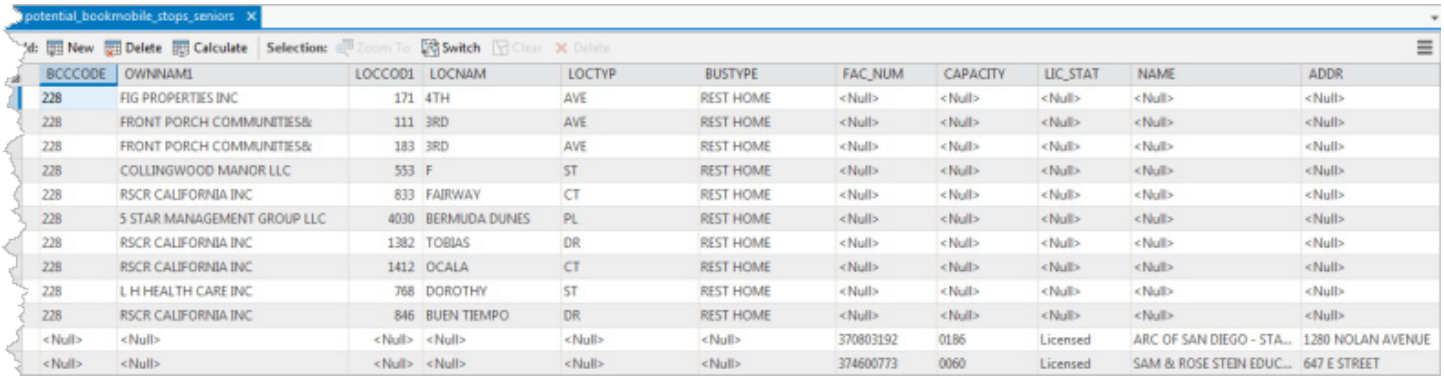
First create the facilities layer by combining the rest homes and the adult day care centers. Select the rest homes in the Business Sites layer. Learn about selecting features using attributes.



Ten features are selected. Now Merge the Business Sites layer and the Adult Day Care layer—only the selected features in the Business Sites layer (the rest homes) will be included in the output layer (along with the two adult day care centers).



Here is the resulting attribute table for the merged layer.



potential_bookmobile_stops_seniors

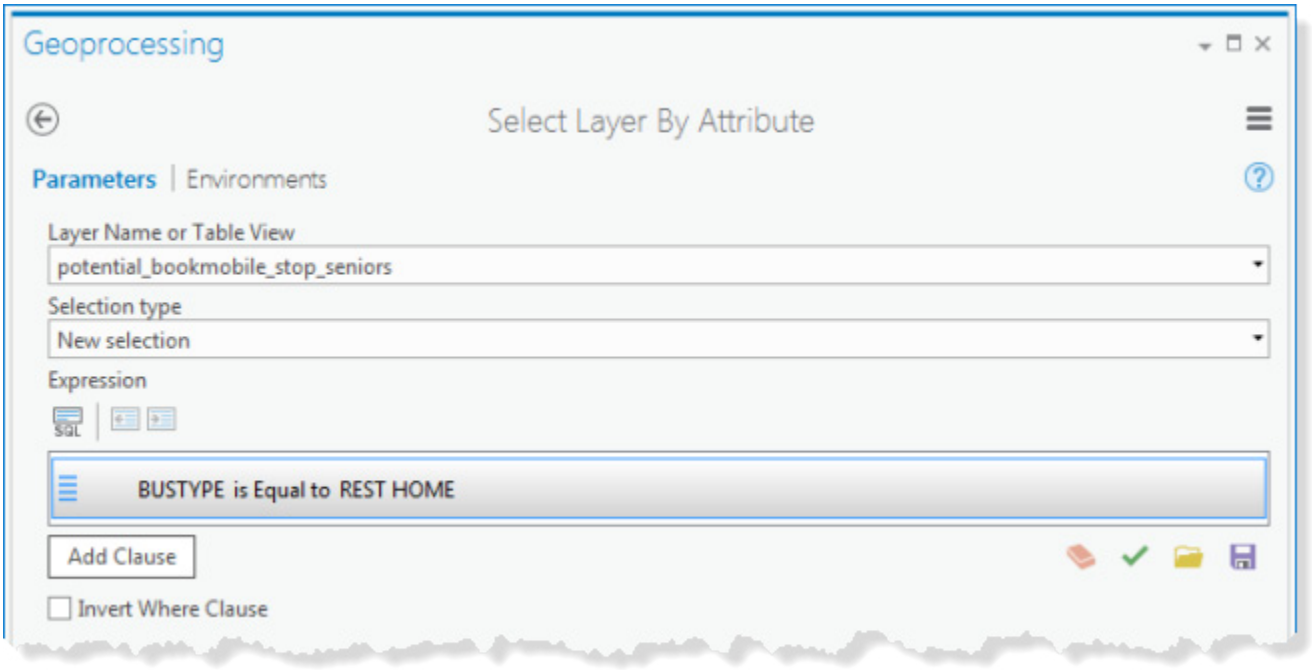
New | Delete | Calculate | Selection: | Switch | Clear | Delete

BCCCODE	OWNNAM1	LOCCOD1	LOCNAM	LOCTYP	BUSTYPE	FAC_NUM	CAPACITY	LIC_STAT	NAME	ADDR
228	FIG PROPERTIES INC	171	4TH	AVE	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	FRONT PORCH COMMUNITIES&	111	3RD	AVE	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	FRONT PORCH COMMUNITIES&	183	3RD	AVE	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	COLLINGWOOD MANOR LLC	553	F	ST	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	RSCR CALIFORNIA INC	833	FAIRWAY	CT	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	5 STAR MANAGEMENT GROUP LLC	4030	BERMUDA DUNES	PL	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	RSCR CALIFORNIA INC	1382	TOBIAS	DR	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	RSCR CALIFORNIA INC	1412	OCALA	CT	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	L H HEALTH CARE INC	768	DOROTHY	ST	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
228	RSCR CALIFORNIA INC	846	BUEN TIEMPO	DR	REST HOME	<Null>	<Null>	<Null>	<Null>	<Null>
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	370803192	0186	Licensed	ARC OF SAN DIEGO - STA...	1280 NOLAN AVENUE
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	374600773	0060	Licensed	SAM & ROSE STEIN EDUC...	647 E STREET

Assign a unique identifier to the facilities

First select the rest homes in the merged layer and calculate Name equal to the concatenated street address. All the fields in the two input layers are carried through to the merged layer. Since the Adult Day Care layer included a field called “Name” but the Business Sites layer didn’t, the rest homes have a value of Null for the Name field. You’ll replace this value with the address for the facility.

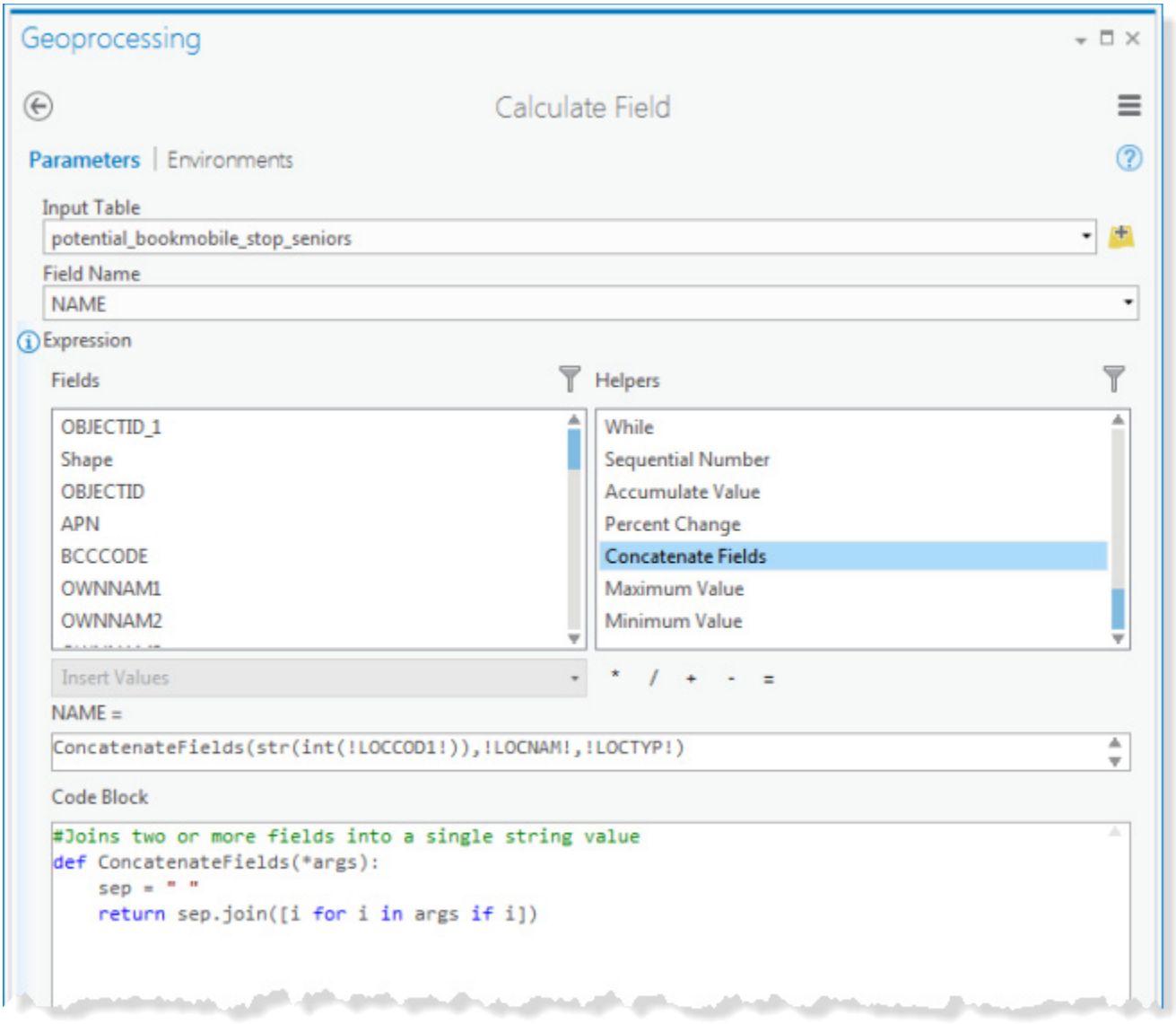
Use Select by Attributes with the BUSTYPE field to select the rest homes.



Now calculate the Name field for the rest homes to be the street address. (Learn about calculating fields.) Since the address is contained in several separate fields you'll need to concatenate the fields to include the street number (LOCCOD1), name (LOCNAM), and type (LOCTYP). Select the Concatenate Fields helper from the list and replace the example fields with the appropriate values. Since the street number (LOCCOD1) is a numeric field with a type of Double, you'll need to include the "int" function convert it first to an Integer type and the "str" function to then convert it to a Text type. The statement should look like this:

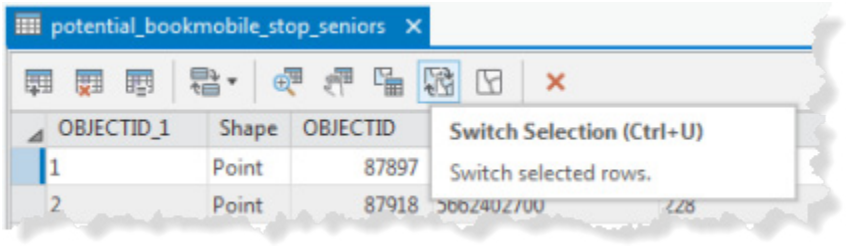
ConcatenateFields(str(int(!LOCCOD1!)), !LOCNAM!, !LOCTYP!)

In the Code Block change the sep character from "-" to " " (space). Otherwise, the address will have hyphens between the street number, name, and type, instead of spaces.



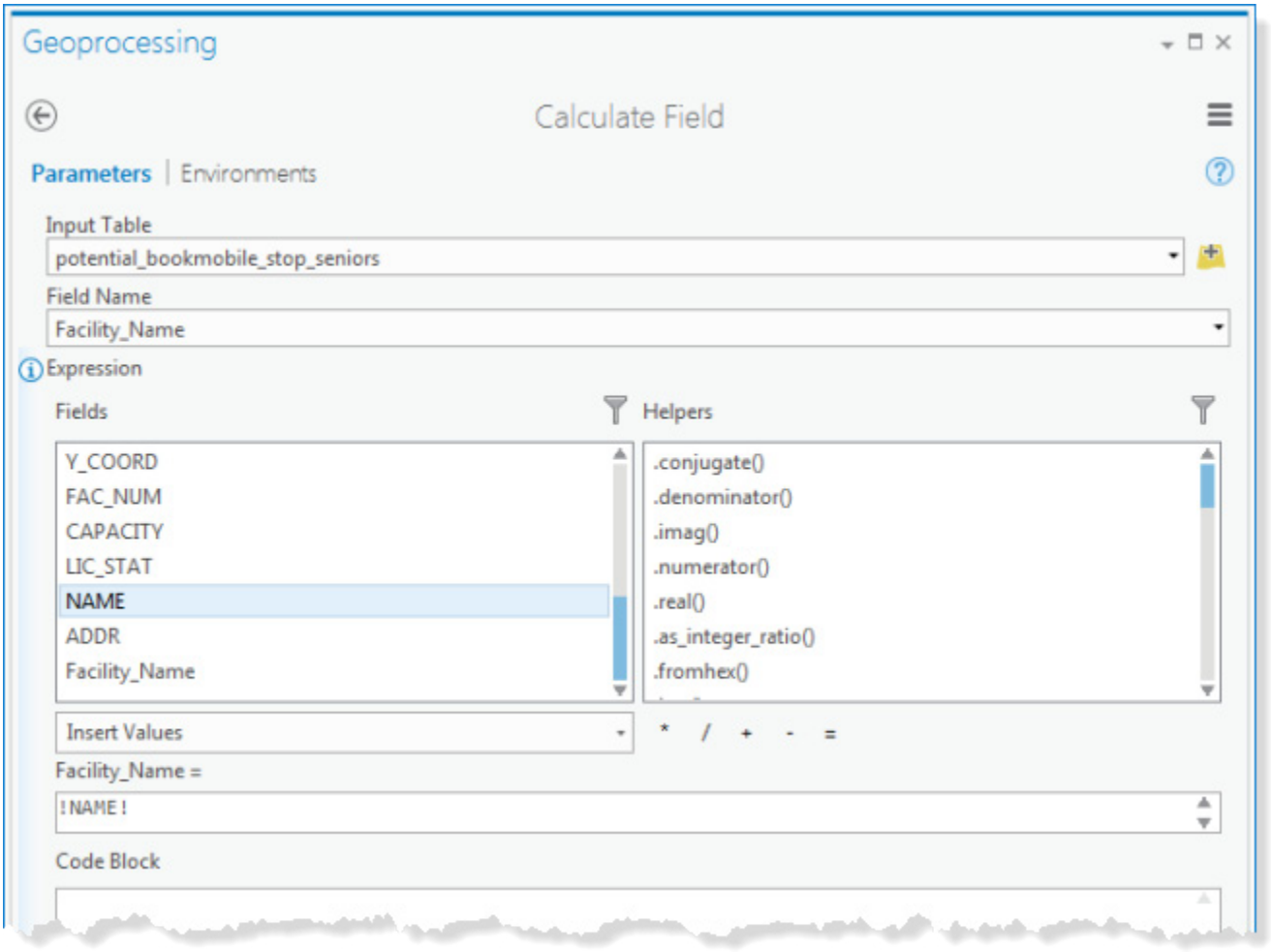
Go ahead and run the Calculate Field tool.

Now, in the attribute table switch the selection to select the two adult day care centers.

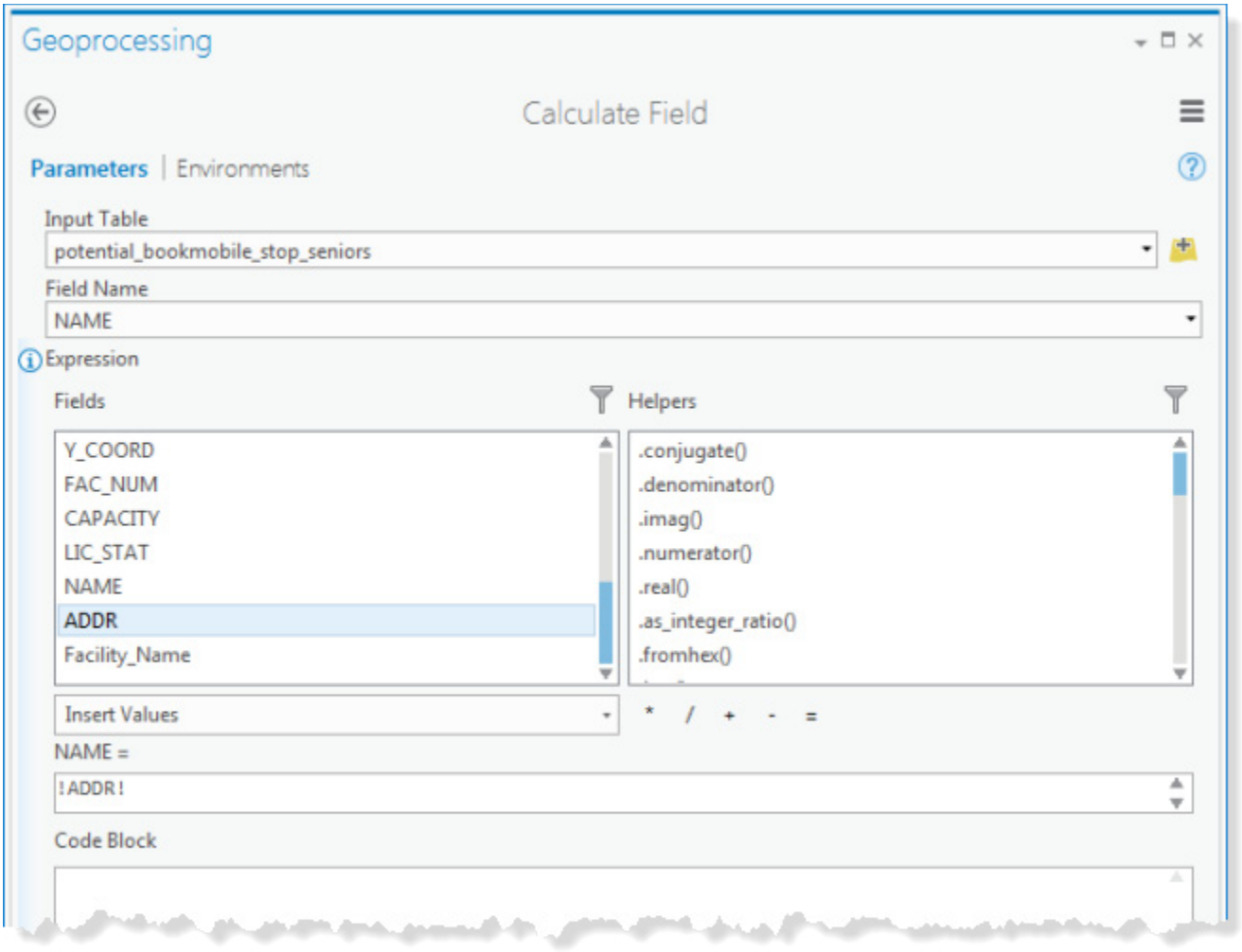


Click the New Field button in the table, and, at the bottom of the list, add the Facility_Name field to store the existing names of the adult day care centers. Be sure to click Save on the Fields tab before closing the Fields View. Learn more about adding and modifying fields.

Calculate Facility_Name equal to Name (since only the adult day care centers are selected, the value will be calculated for those two records alone).



Finally, With the two adult day care centers still selected, calculate Name equal to ADDR (the street address).



Now all the stops have a street address in the Name field. Here is the resulting attribute table for the facilities layer.

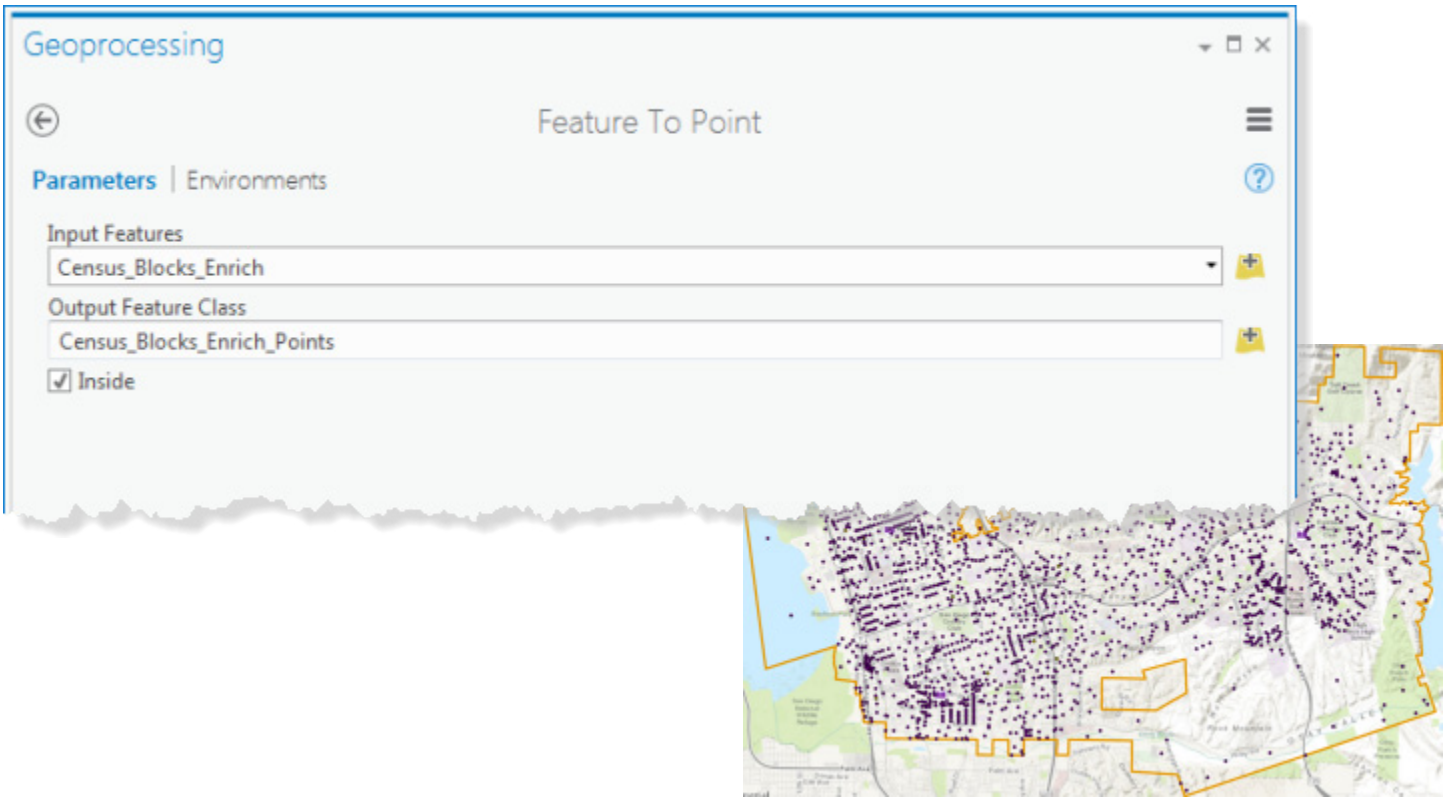
potential_bookmobile_stops_seniors

OWNNAM1	LOCCOD1	LOCNAM	LOCTYP	BUSTYPE	FAC_NUM	CAPACITY	LIC_STAT	NAME	ADDR	Facility_Name
FIG PROPERTIES INC	171	4TH	AVE	REST HOME	<Null>	<Null>	<Null>	171 4TH AVE	<Null>	<Null>
FRONT PORCH COM...	111	3RD	AVE	REST HOME	<Null>	<Null>	<Null>	111 3RD AVE	<Null>	<Null>
FRONT PORCH COM...	183	3RD	AVE	REST HOME	<Null>	<Null>	<Null>	183 3RD AVE	<Null>	<Null>
COLLINGWOOD MA...	553	F	ST	REST HOME	<Null>	<Null>	<Null>	553 F ST	<Null>	<Null>
RSCR CALIFORNIA INC	833	FAIRWAY	CT	REST HOME	<Null>	<Null>	<Null>	833 FAIRWAY CT	<Null>	<Null>
5 STAR MANAGEME...	4030	BERMUDA DUNES	PL	REST HOME	<Null>	<Null>	<Null>	4030 BERMUDA DUN...	<Null>	<Null>
RSCR CALIFORNIA INC	1382	TOBIAS	DR	REST HOME	<Null>	<Null>	<Null>	1382 TOBIAS DR	<Null>	<Null>
RSCR CALIFORNIA INC	1412	OCALA	CT	REST HOME	<Null>	<Null>	<Null>	1412 OCALA CT	<Null>	<Null>
L H HEALTH CARE INC	768	DOROTHY	ST	REST HOME	<Null>	<Null>	<Null>	768 DOROTHY ST	<Null>	<Null>
RSCR CALIFORNIA INC	846	BUEN TIEMPO	DR	REST HOME	<Null>	<Null>	<Null>	846 BUEN TIEMPO DR	<Null>	<Null>
<Null>	<Null>	<Null>	<Null>	<Null>	370803192	0186	Licensed	1280 NOLAN AVENUE	1280 NOLAN AVENUE	ARC OF SAN DIEGO -...
<Null>	<Null>	<Null>	<Null>	<Null>	374600773	0060	Licensed	647 E STREET	647 E STREET	SAM & ROSE STEIN E...

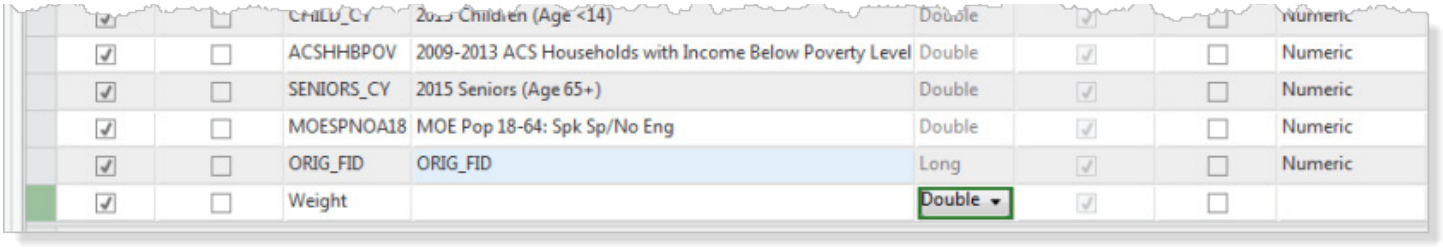
Clear all the selections before continuing.

Create the demand locations layer

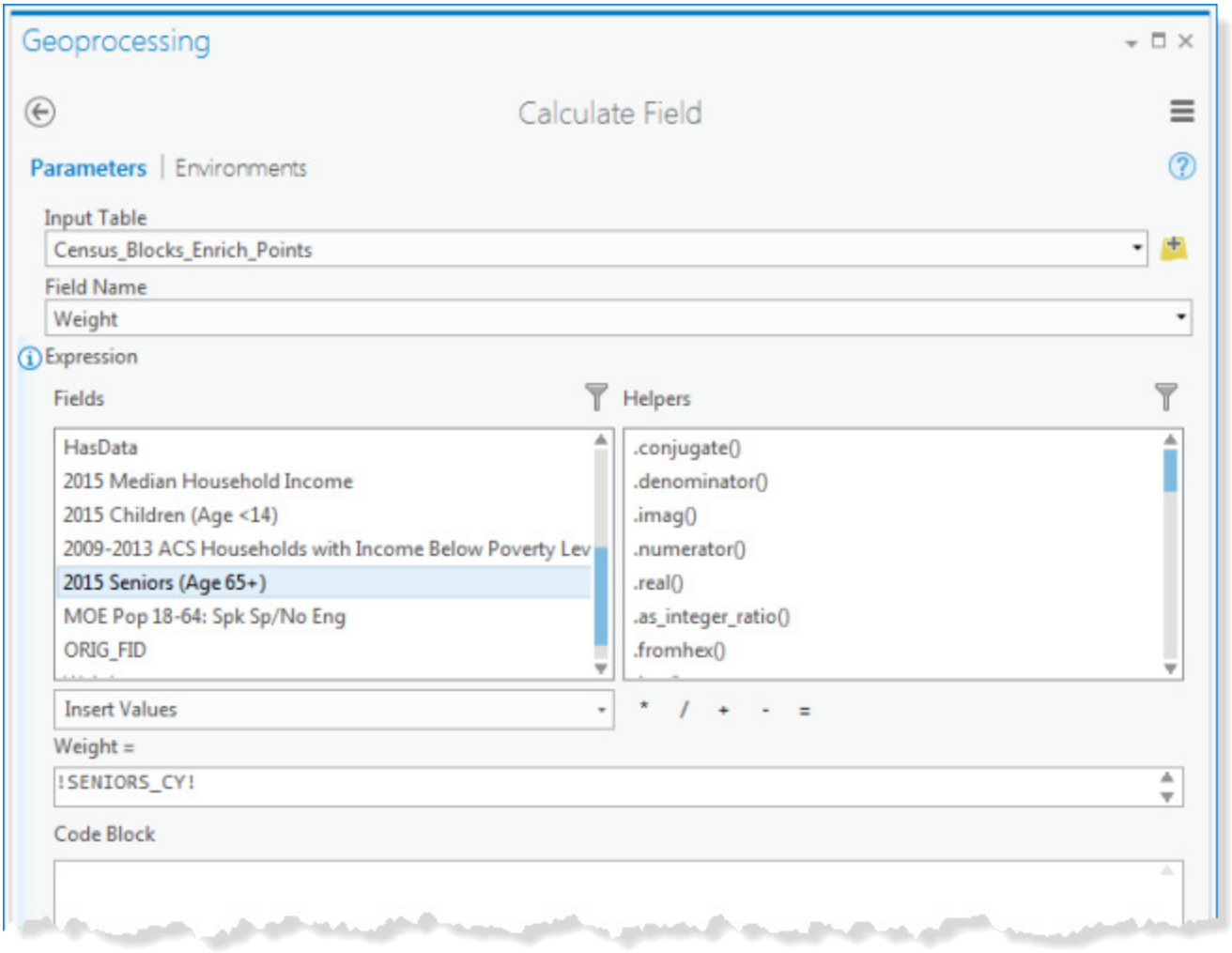
Location-Allocation requires that both the facilities and the demand locations (representing census blocks, in this example) be point features. The facilities (Business Sites and Adult Day Care Centers) were existing point features. However the enriched census blocks are polygons so you need to create a point layer from them using the Feature to Point tool. Be sure to check the Inside box to ensure the points fall within their corresponding census block boundaries.



Location-Allocation looks for a field named Weight containing the demand values (the number of seniors, in this example). Add the Weight field to the census block point layer….



….and calculate it equal to the Seniors (Age 65+) field.

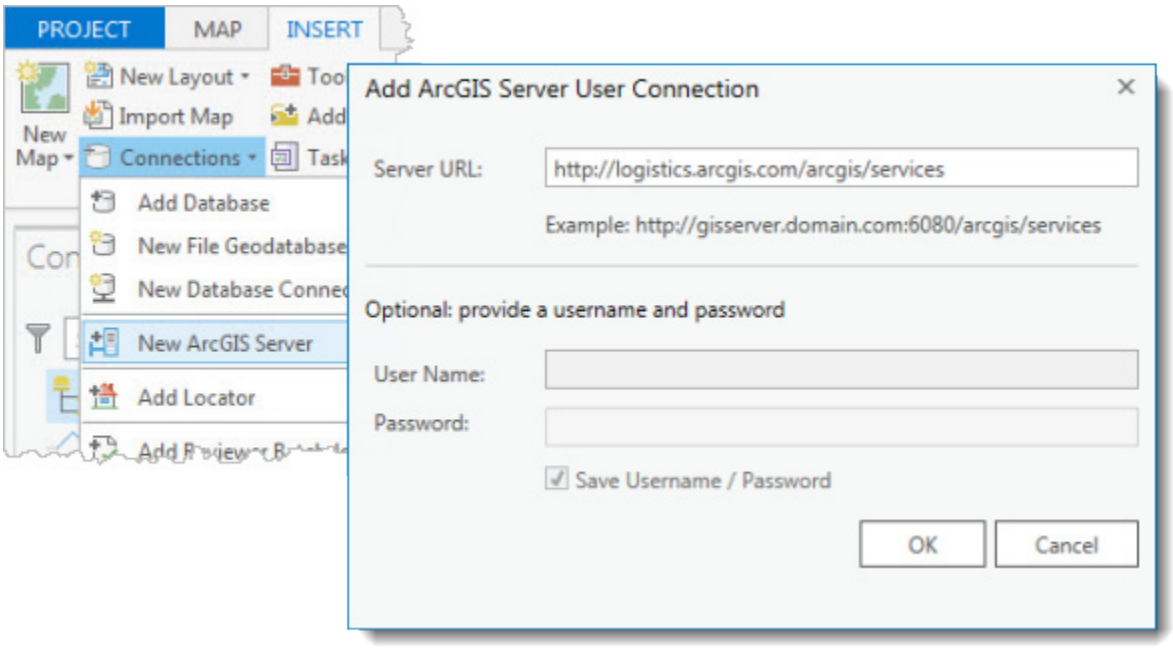


In the table, the Weight values are now equal to the values in the Seniors (Age 65+) field.

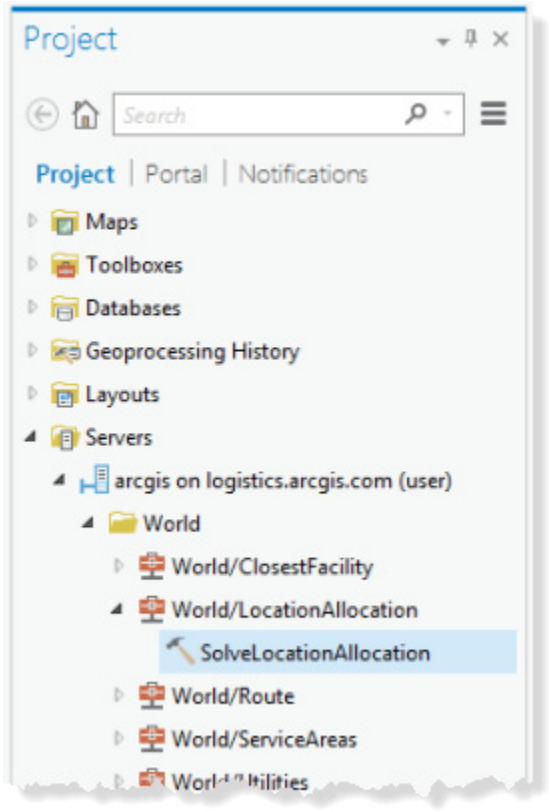
ome Below Poverty Level	2015 Seniors (Age 65+)	ACS Pop 18-64: Spk Sp/Eng NW	ORIG_FID	Weight
0	0	0	1	0
1	0	0	2	0
0	0	0	3	0
0	0	0	4	0
0	0	0	5	0
252	313	99	6	313
0	0	0	7	0
94	99	47	8	99
0	11	5	9	11
0	46	9	10	46

Run the Location-Allocation analysis

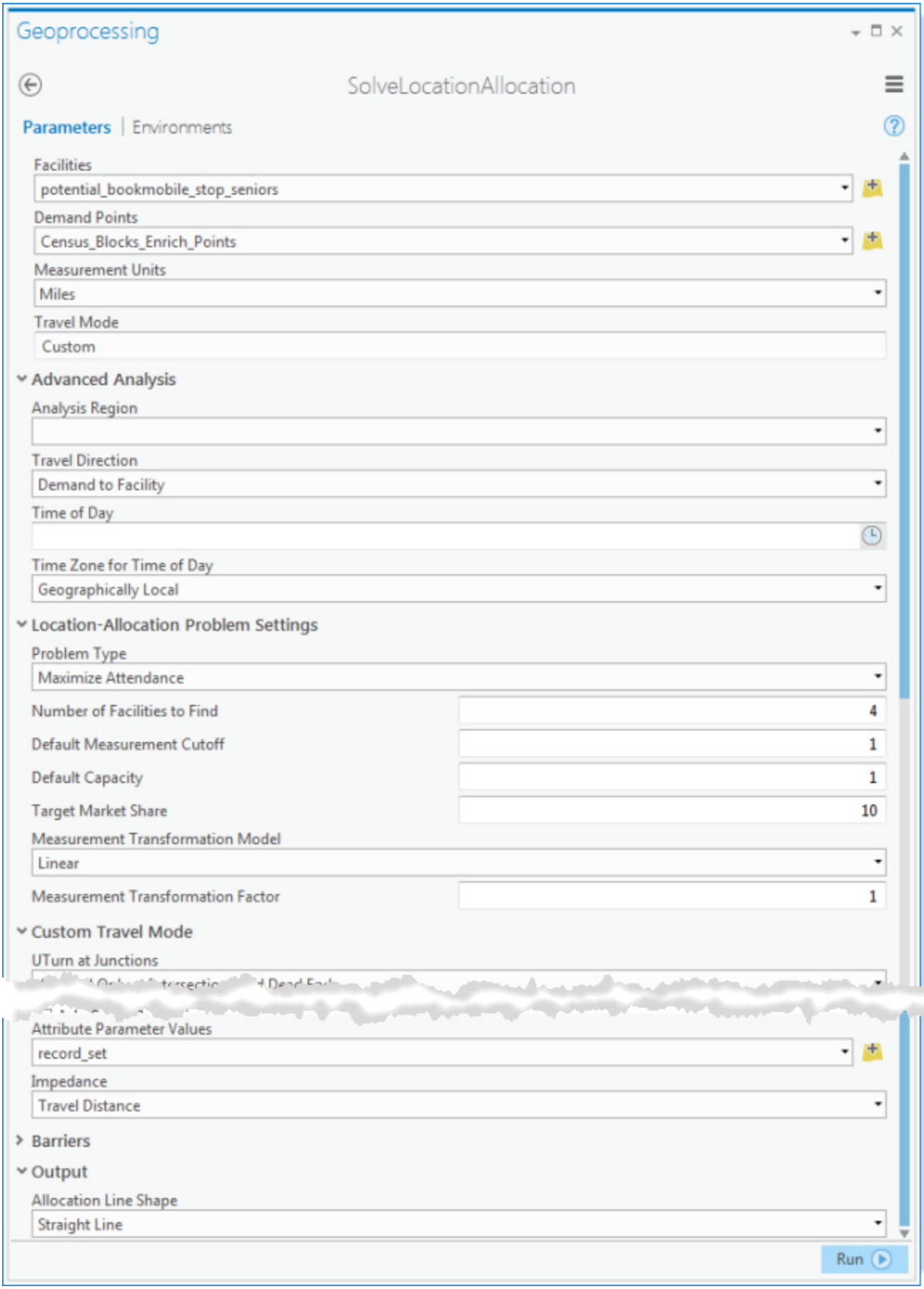
With the layers ready to go you can now run the Location-Allocation analysis to find the four optimal sites. You first need to add an ArcGIS server connection to access the SolveLocationAllocation tool. Click the Connections dropdown on the Insert tab, and click New ArcGIS Server. Add the following Server URL in the dialog box: http://logistics.arcgis.com/arcgis/services. Learn more about adding an ArcGIS server connection.



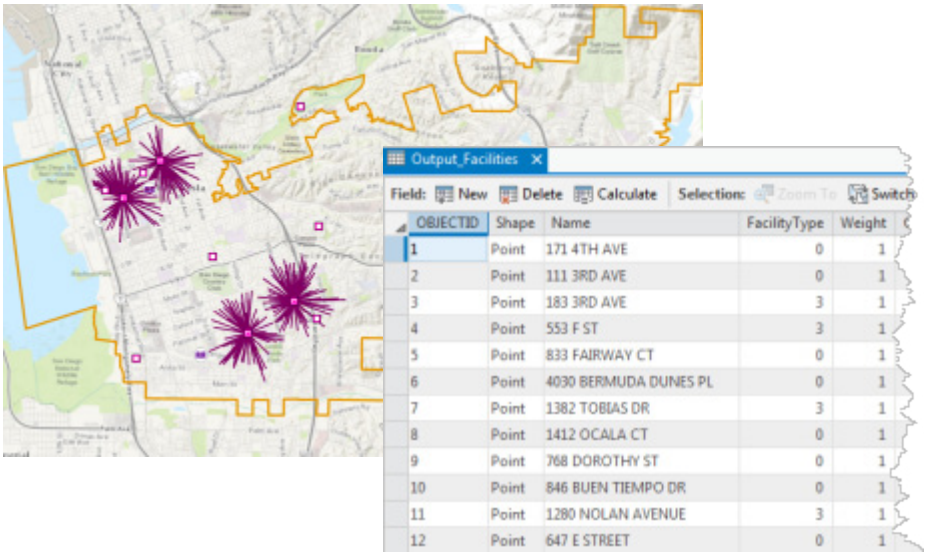
Now, in the Project pane, open the SolveLocationAllocation tool (in the Servers folder).



Specify the Facilities and Demand Points, and set the Measurement Units to Miles. Under Advanced Analysis specify the Travel Direction as Demand to Facility. Specify the Location-Allocation Problem Settings as shown below, and under Custom Travel Mode set the Impedance to Travel Distance. (Since you're specifying a measurement cutoff in miles—one mile, to be exact—you need to make sure the Measurement Units are set to miles and the Impedance is set to travel distance rather than travel time.) Use the defaults for the rest of the settings. Learn more about SolveLocationAllocation.


Geoprocessing
SolveLocationAllocation
Parameters | Environments
Facilities
potential_bookmobile_stop_seniors
Demand Points
Census_Blocks_Enrich_Points
Measurement Units
Miles
Travel Mode
Custom
Advanced Analysis
Analysis Region
Travel Direction
Demand to Facility
Time of Day
Time Zone for Time of Day
Geographically Local
Location-Allocation Problem Settings
Problem Type
Maximize Attendance
Number of Facilities to Find
4
Default Measurement Cutoff
1
Default Capacity
1
Target Market Share
10
Measurement Transformation Model
Linear
Measurement Transformation Factor
1
Custom Travel Mode
UTurn at Junctions
Attribute Parameter Values
record_set
Impedance
Travel Distance
Barriers
Output
Allocation Line Shape
Straight Line
Run

The tool finds the four optimal senior facility stops (you'll get a warning that some of the census blocks have a weight of 0—that is, no seniors living in them. Not a problem). In the output facilities layer, the FacilityType field indicates the chosen facilities (a value of 3).



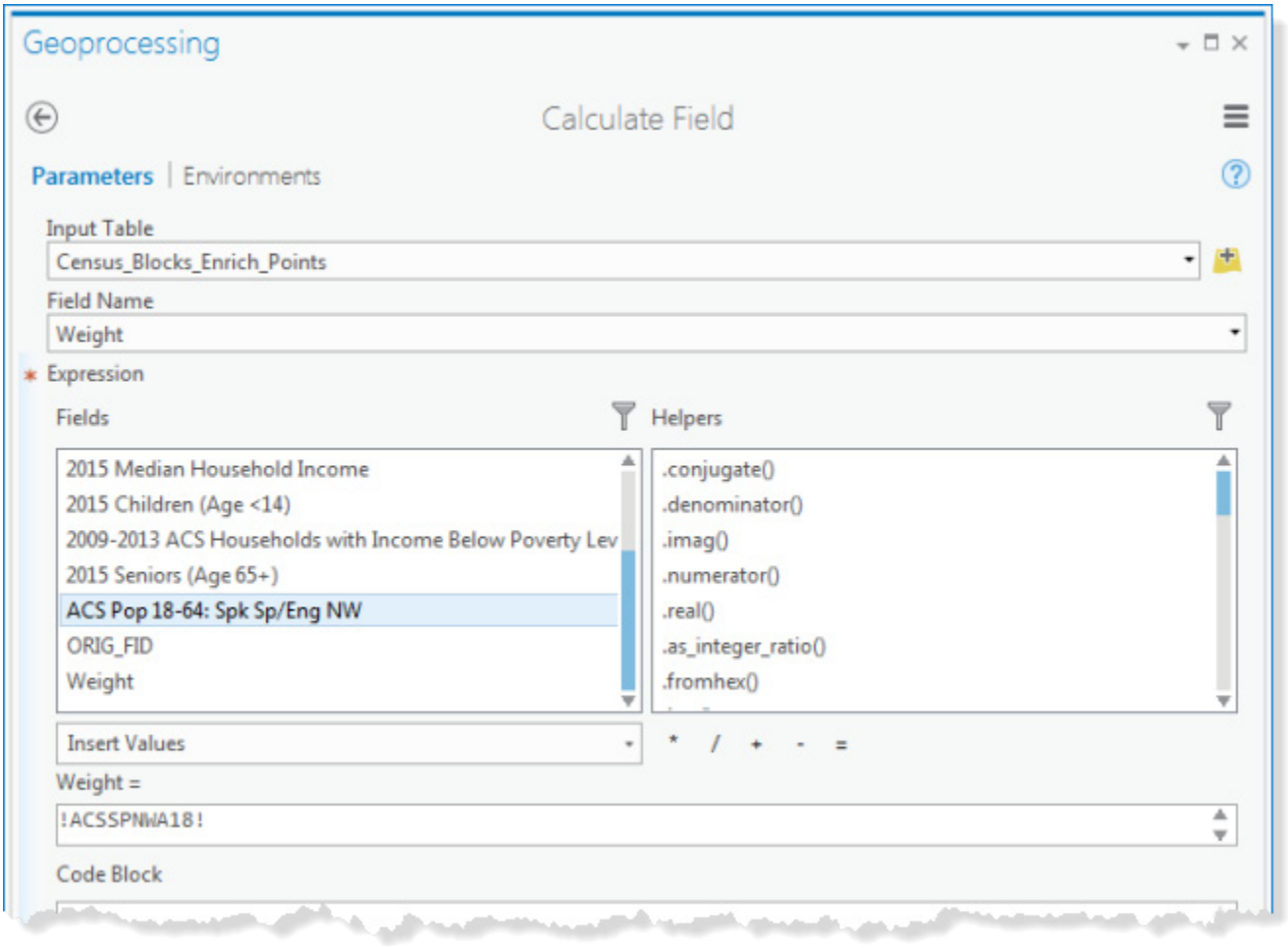
OBJECTID	Shape	Name	FacilityType	Weight
1	Point	171 4TH AVE	0	1
2	Point	111 3RD AVE	0	1
3	Point	183 3RD AVE	3	1
4	Point	553 F ST	3	1
5	Point	833 FAIRWAY CT	0	1
6	Point	4030 BERMUDA DUNES PL	0	1
7	Point	1382 TOBIAS DR	3	1
8	Point	1412 OCALA CT	0	1
9	Point	768 DOROTHY ST	0	1
10	Point	846 BUEN TIEMPO DR	0	1
11	Point	1280 NOLAN AVENUE	3	1
12	Point	647 E STREET	0	1

Find the optimal retail center stops

The steps for finding the optimal retail center stops are similar, but you'll do them in a slightly different order: create the demand locations layer, create the facilities layer, and then run the Location-Allocation analysis.

Create the demand locations layer

You'll reuse the Census_Blocks_Enrich_Point layer as the demand locations, replacing the Weight value, currently representing seniors, with the population of Spanish-speaking adults.

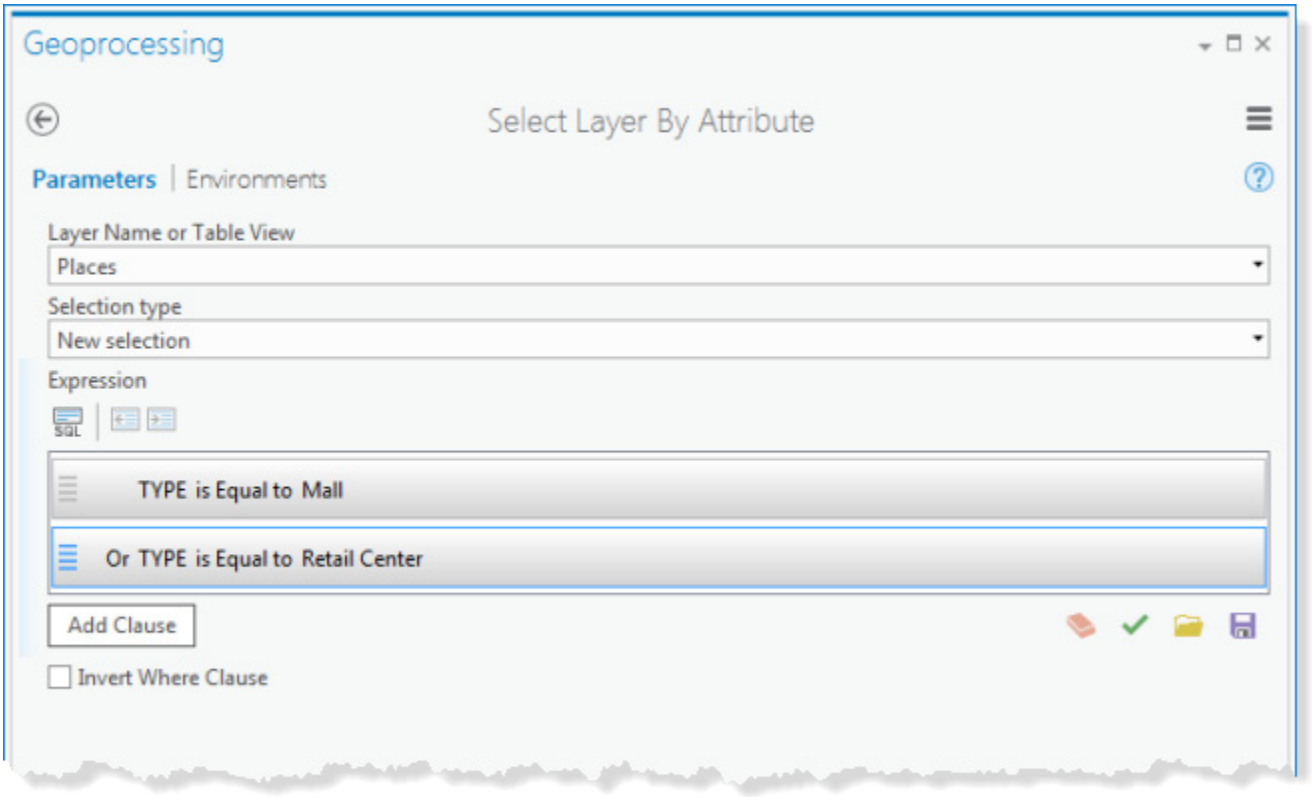


In the demand locations layer attribute table, the values in the Weight field now equal the values in the ACS Pop 18-64: Spk Sp/Eng NW field.

2015 Seniors (Age 65+)	ACS Pop 18-64: Spk Sp/Eng NW	ORIG_FID	Weight
0	0	1	0
0	0	2	0
0	0	3	0
0	0	4	0
0	0	5	0
313	99	6	99
0	0	7	0
99	47	8	47
11	5	9	5
46	9	10	9
0	0	11	0
172	104	12	104

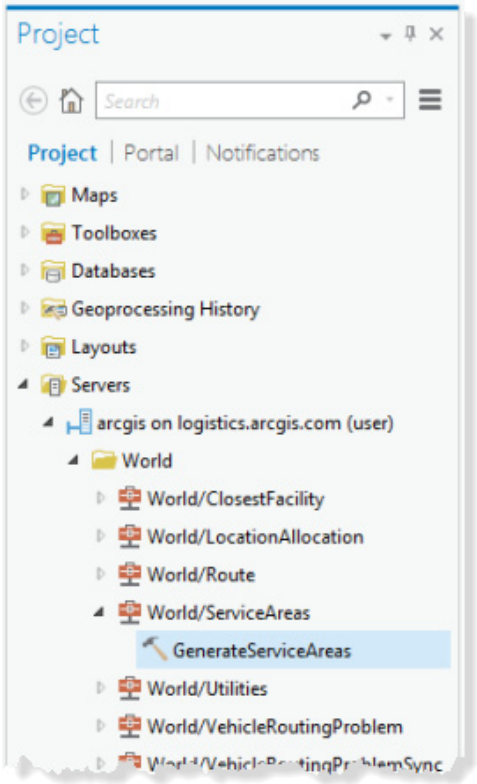
Create the facilities layer

Select the malls and retail centers in the Places layer.

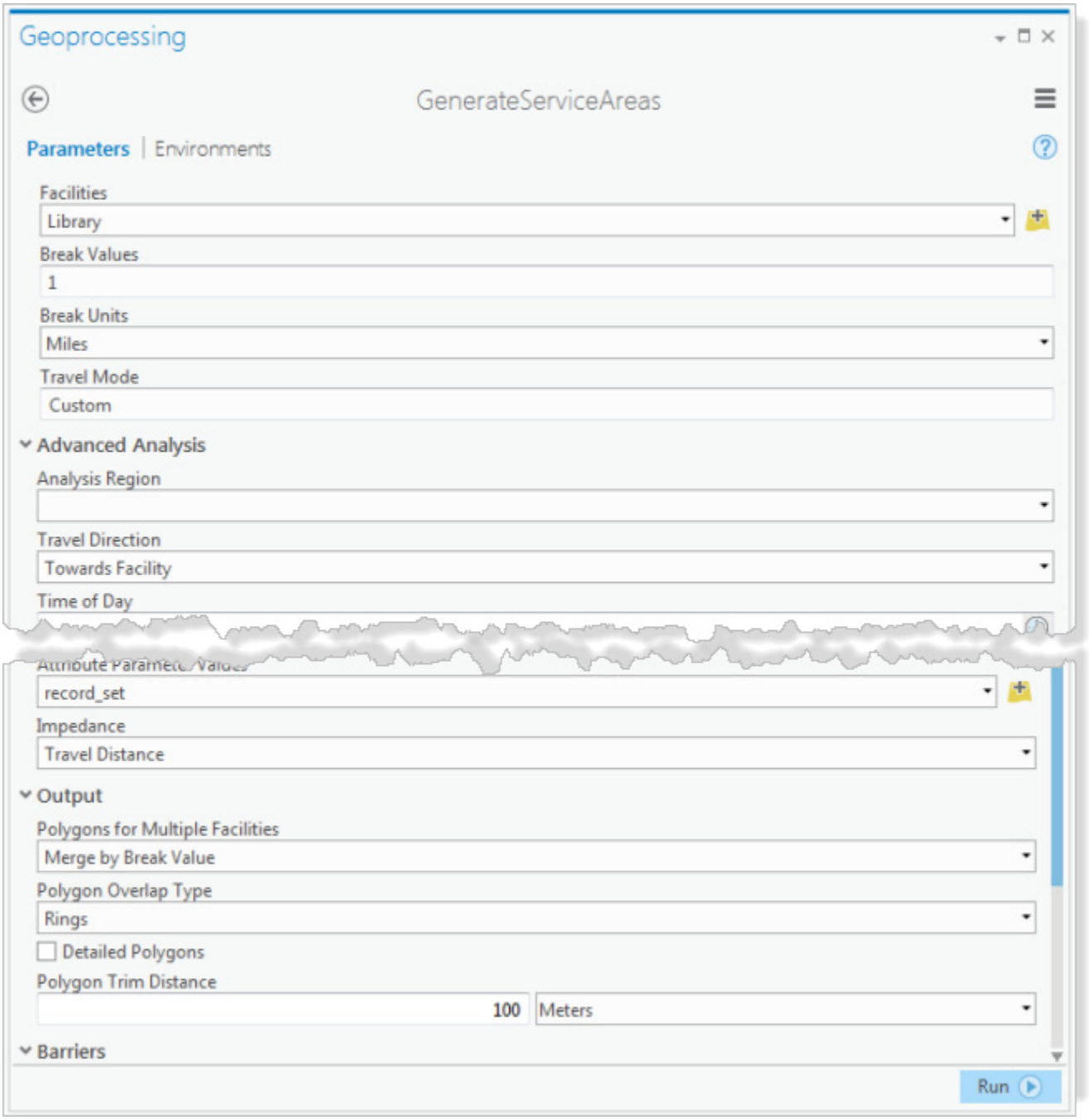


30 features are selected.

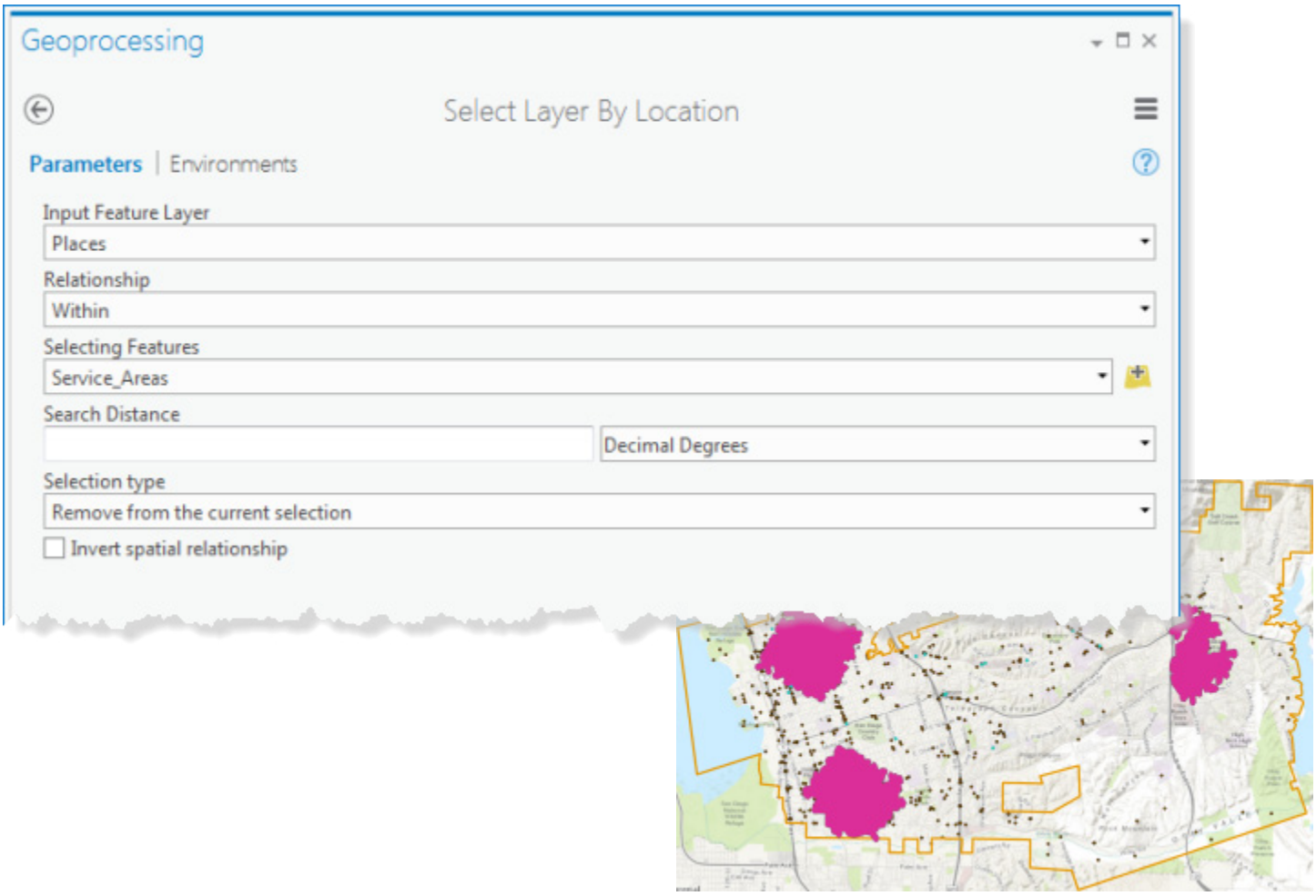
In the Project pane, open the GenerateServiceAreas tool to create the 1-mile service areas around branch libraries.



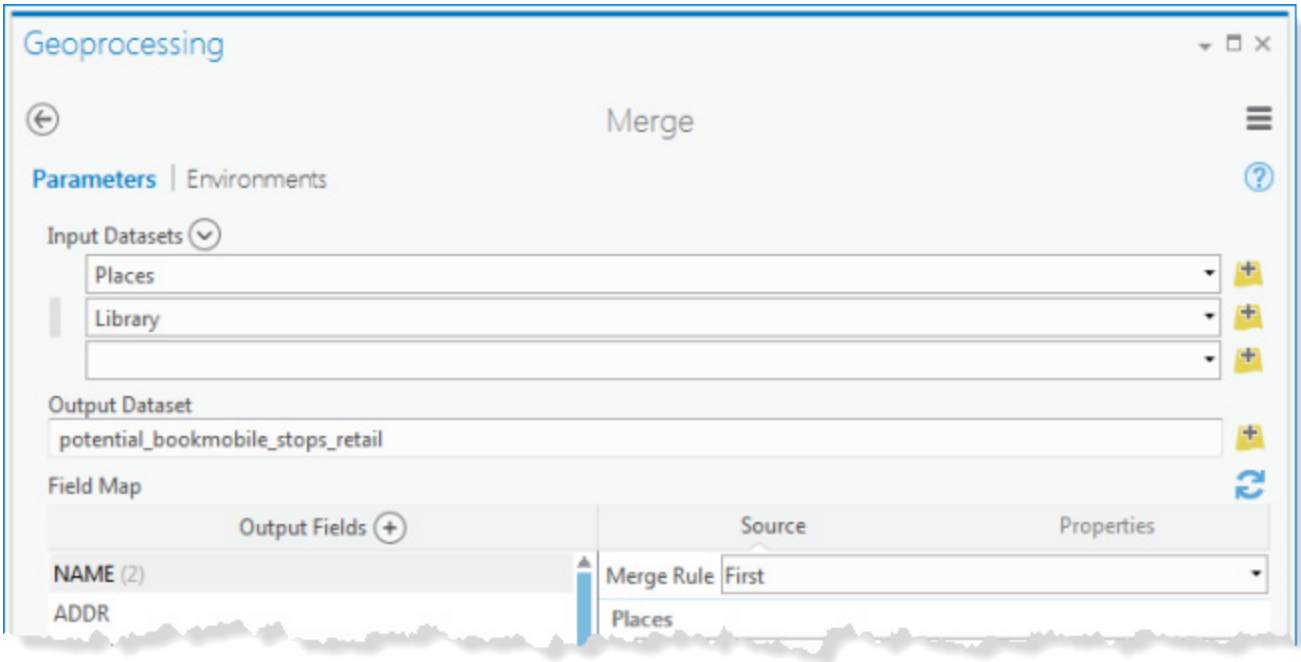
Specify Break Values as 1 (mile) and set the Break Units to Miles. Under Advanced Analysis, set the Travel Direction to Towards Facility. Under Custom Travel Mode, specify Travel Distance for the Impedance. Finally, under Output, specify Merge by Break Value. This will create a single feature in the output layer. (The default setting of Overlapping would create three separate features, one surrounding each library branch. While this will suit your immediate purpose for Select Layer by Location, creating the layer with a single feature now will simplify the analysis later in the workflow when summarizing the population within a mile of any library branch.)



Use select by location to exclude malls and retail centers within the 1-mile service areas. Specify Selection Type as Remove from the current selection (since malls and retail centers are the currently selected features in the Places layer).

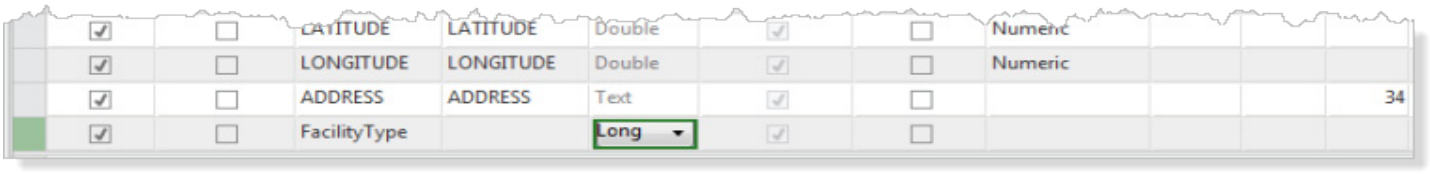


Merge the Places layer with the Library layer to create the facilities layer (only the selected features in the Places layer—the malls and retail centers—will be included in the output).

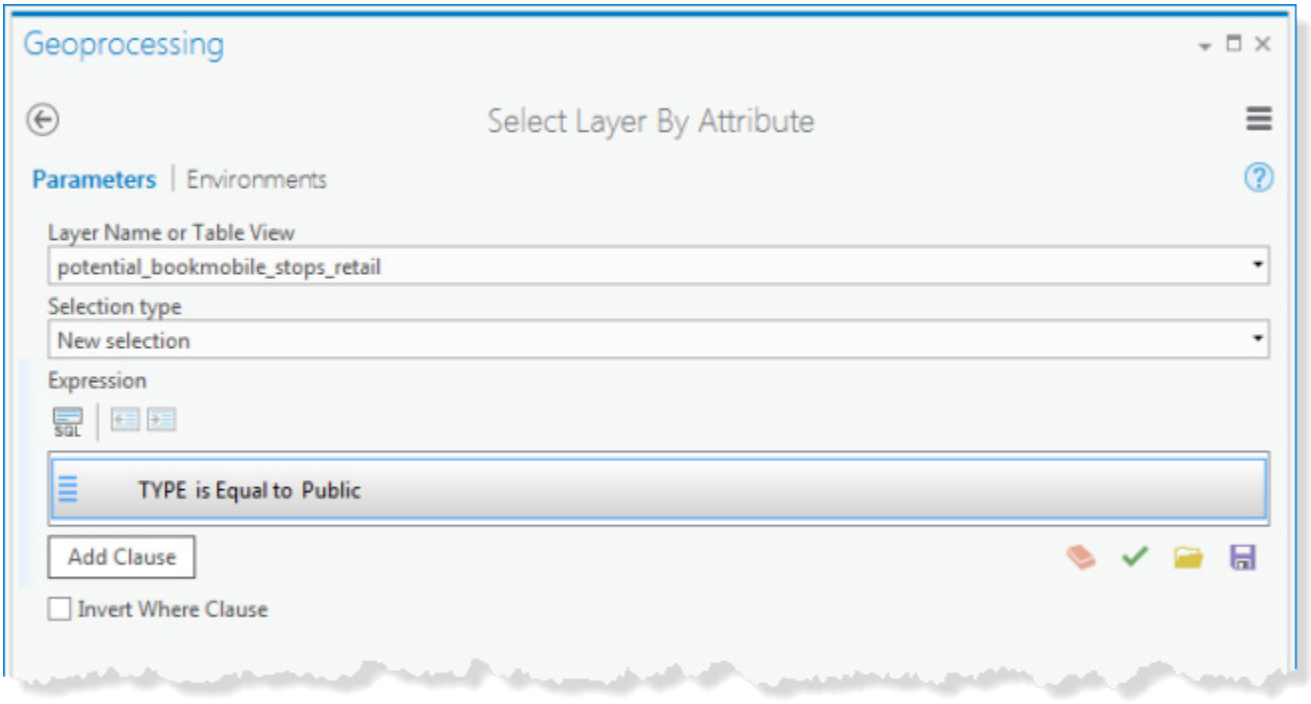


After the Merge is completed, clear the selected features in the Places layer.

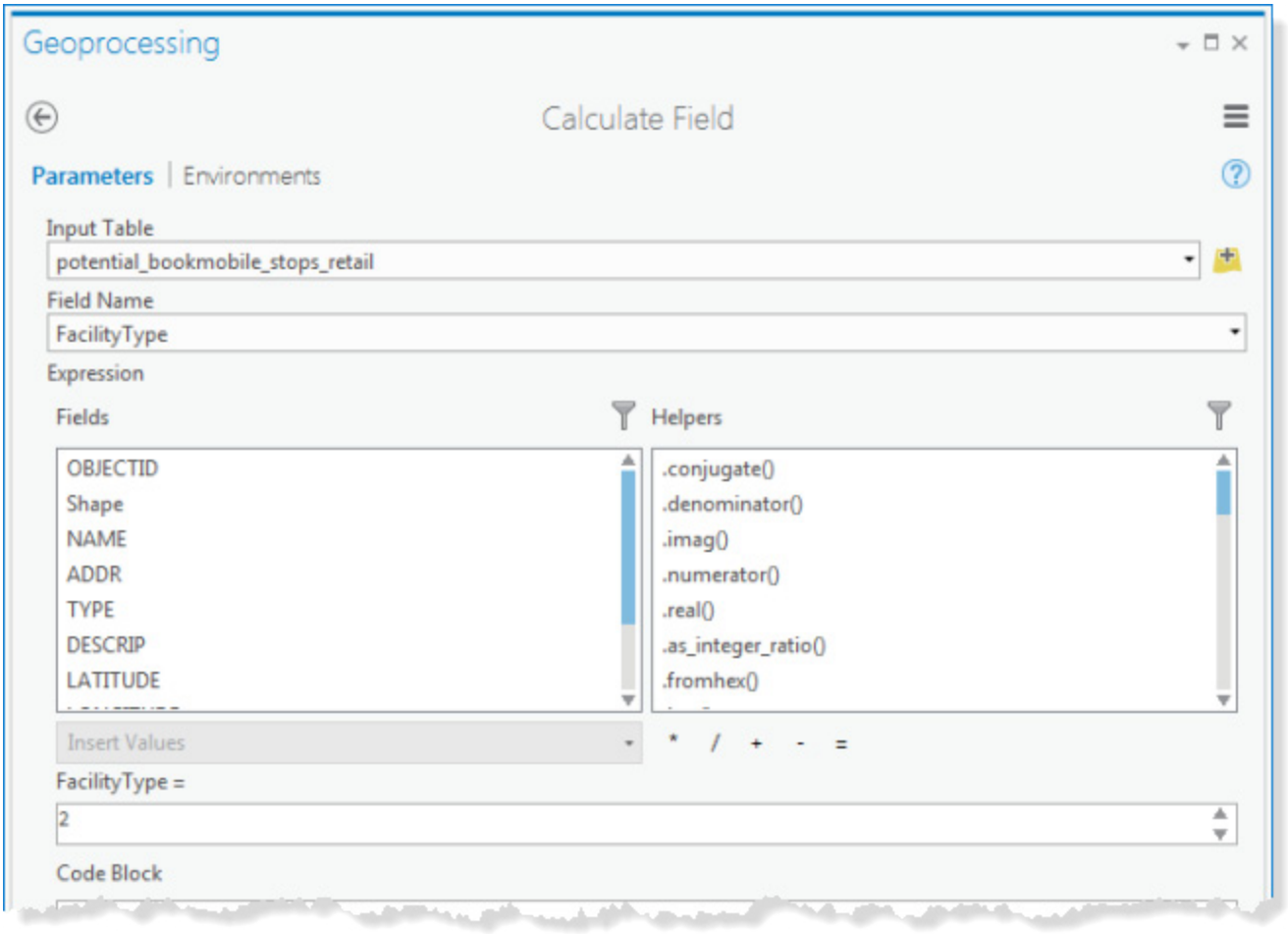
Add the FacilityType field that will be used by Location-Allocation to distinguish the candidate facilities (the bookmobile stops) from the competitor facilities (the library branches). Candidates are assigned a value of 0 and competitors a value of 2. (For the senior facilities, all the facilities were candidates—there were no competitors. If FacilityType is not specified SolveLocationAllocation assumes all the facilities are candidates, so it was not necessary to add the FacilityType field before running the tool. In that case, SolveLocationAllocation adds the field and indicates which facilities are chosen).



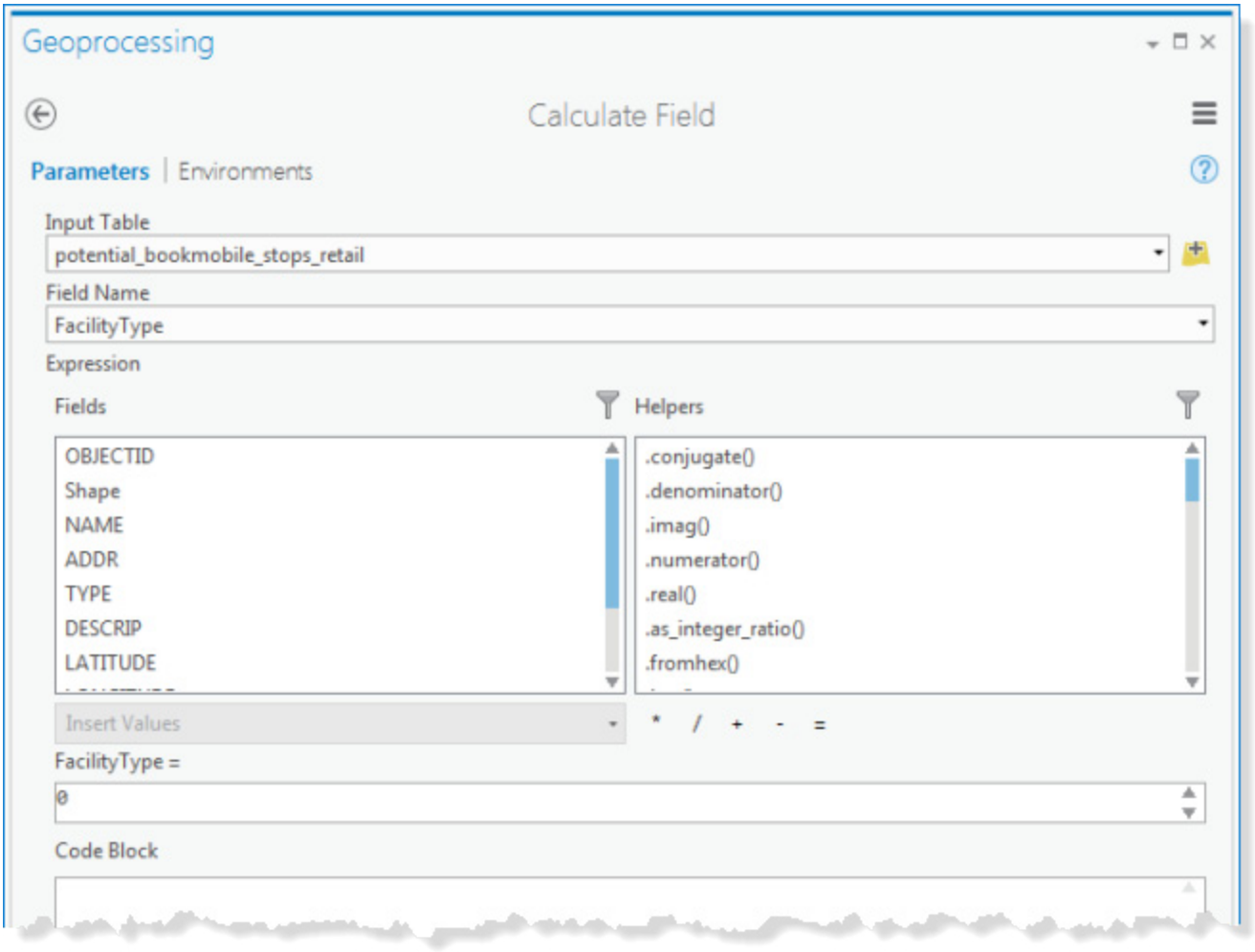
Select the Libraries….



….and calculate FacilityType = 2.



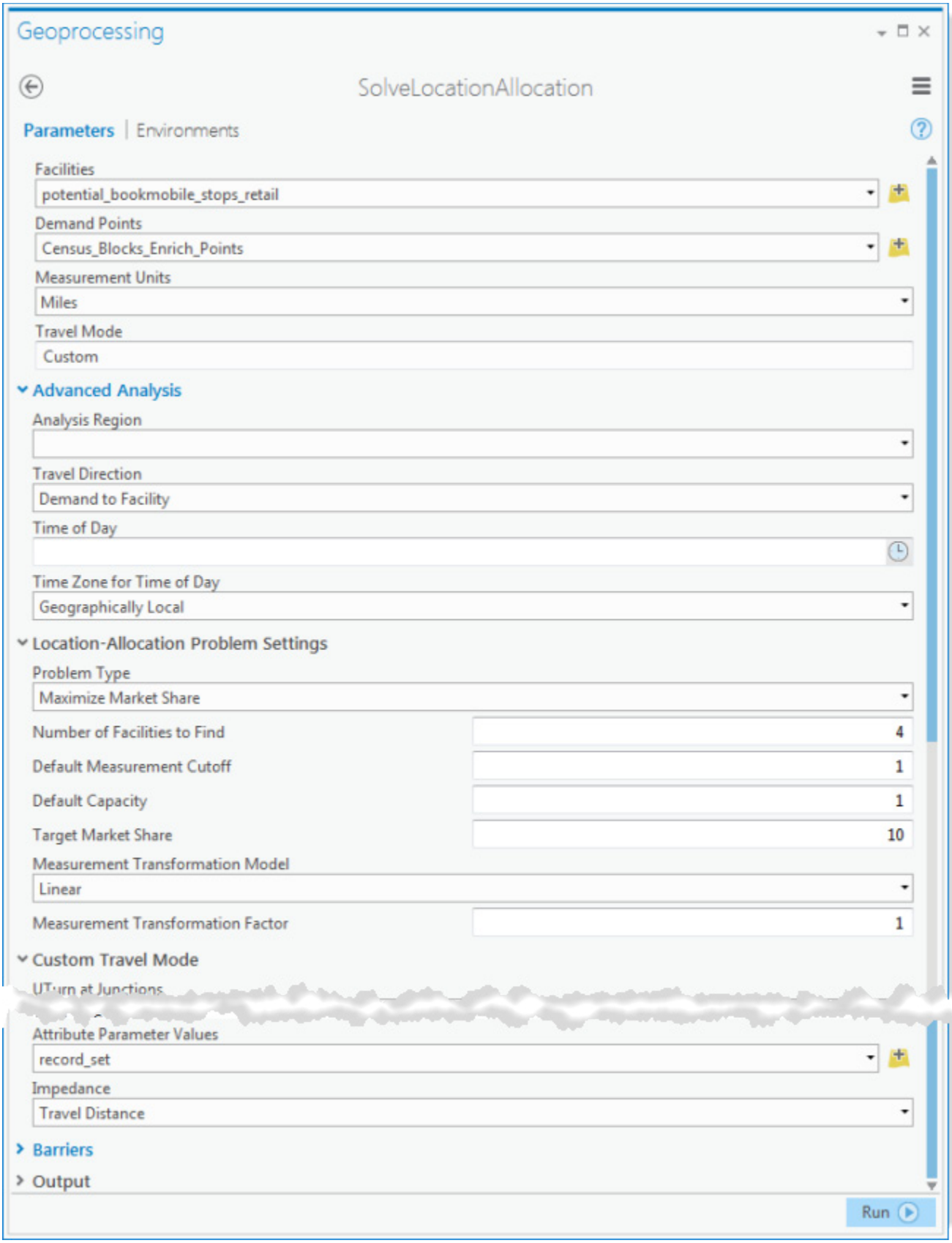
Switch the selection to select the retail centers and malls, and calculate FacilityType = 0.



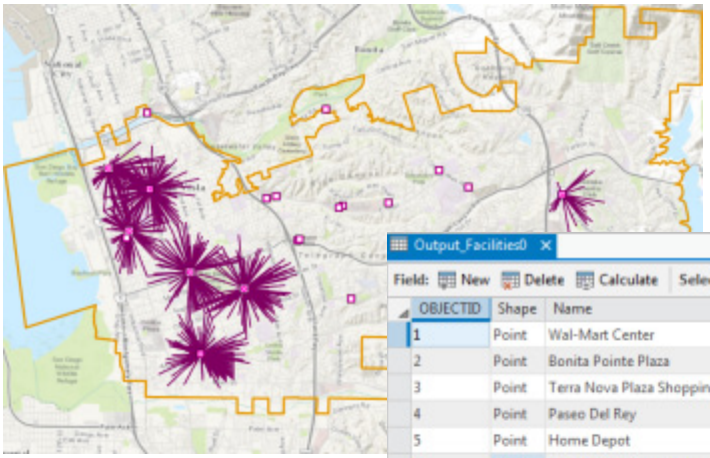
Then clear the selection.

Run the Location-Allocation analysis

With the facility layer and the demand location layer ready to go you can now run the Location-Allocation analysis to find the four optimal sites. This time you'll specify the Maximize Market Share problem type.
On the Project pane, open the SolveLocationAllocation tool (in the Servers folder). As before, specify the Facilities and Demand Points, and set the Measurement Units to Miles. Under Advanced Analysis specify the Travel Direction as Demand to Facility. Specify the Location-Allocation Problem Settings as shown below, and under Custom Travel Mode set the Impedance to Travel Distance. Use the defaults for the rest of the settings.



The tool finds the four stops that will serve the greatest number of adults speaking Spanish-only, assuming the existing branches draw some potential bookmobile patrons.



Output_Facilities0

Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

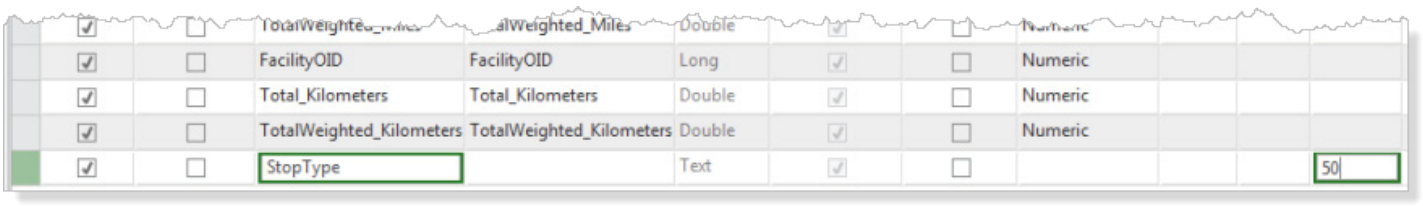
OBJECTID	Shape	Name	FacilityType	Weight	Capacity	DemandCount	DemandWeight
1	Point	Wal-Mart Center	3	1	<Null>	73	710.175283
2	Point	Bonita Pointe Plaza	0	1	<Null>	0	0
3	Point	Terra Nova Plaza Shopping Center	0	1	<Null>	0	0
4	Point	Paseo Del Rey	0	1	<Null>	0	0
5	Point	Home Depot	0	1	<Null>	0	0
6	Point	Chula Vista Shopping Center	3	1	<Null>	87	606.921904
7	Point	Canyon Plaza	0	1	<Null>	0	0
8	Point	Bonita Center	0	1	<Null>	0	0
9	Point	The Plaza at Sunbow	0	1	<Null>	0	0
10	Point	Rio Sweetwater Plaza Shopping Center	0	1	<Null>	0	0
11	Point	Canyon Plaza Shopping Center	0	1	<Null>	0	0
12	Point	Rancho del Rey Shopping Center	0	1	<Null>	0	0
13	Point	Chula Vista Square Shopping Center	0	1	<Null>	0	0
14	Point	Southwestern College Estates Shopping Center	0	1	<Null>	0	0
15	Point	Country Club Shopping Center	3	1	<Null>	92	596.076722
16	Point	Country Club Square Shopping Center	3	1	<Null>	109	729.264681
17	Point	Terra Nova Plaza Shopping Center	0	1	<Null>	0	0
18	Point	Civic Center Branch	2	1	<Null>	115	695.721332
19	Point	EastLake Branch	2	1	<Null>	23	120
20	Point	South Branch	2	1	<Null>	126	999.840079

Case Study Section: Creating the routes and schedules

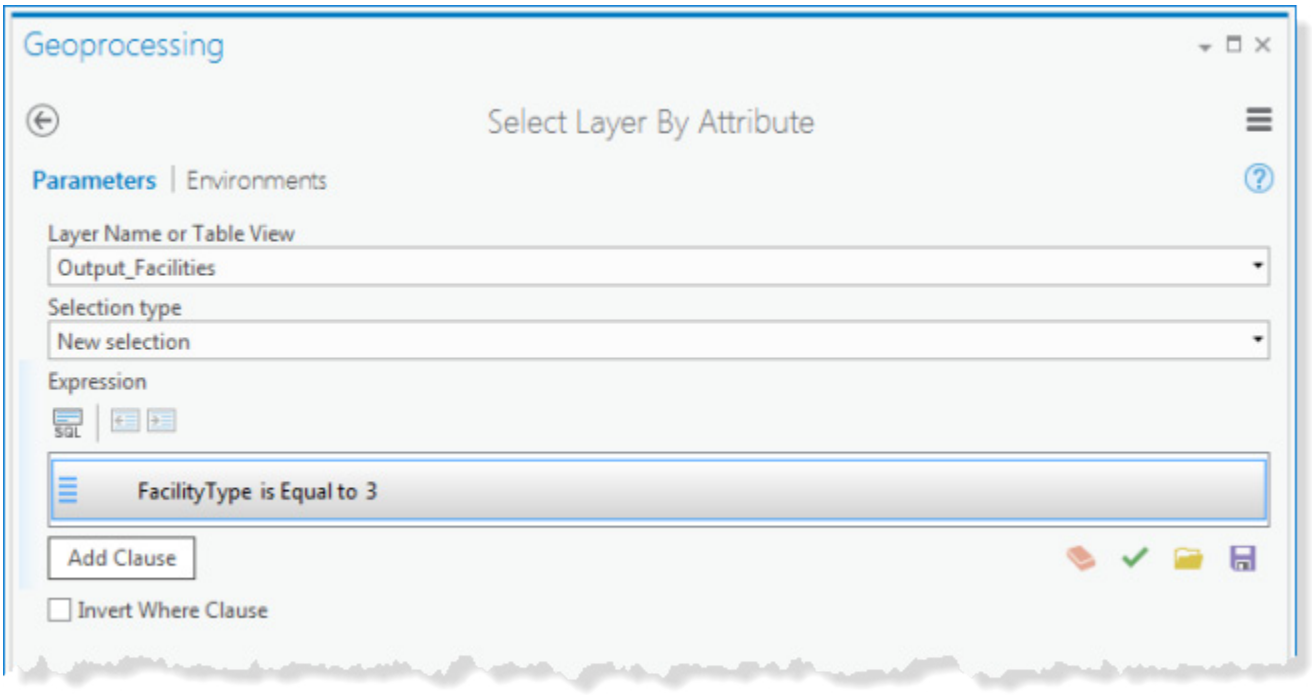
- Create the combined stops layer
- Create the routes and schedules
- Create the route maps and table

Create the combined stops layer

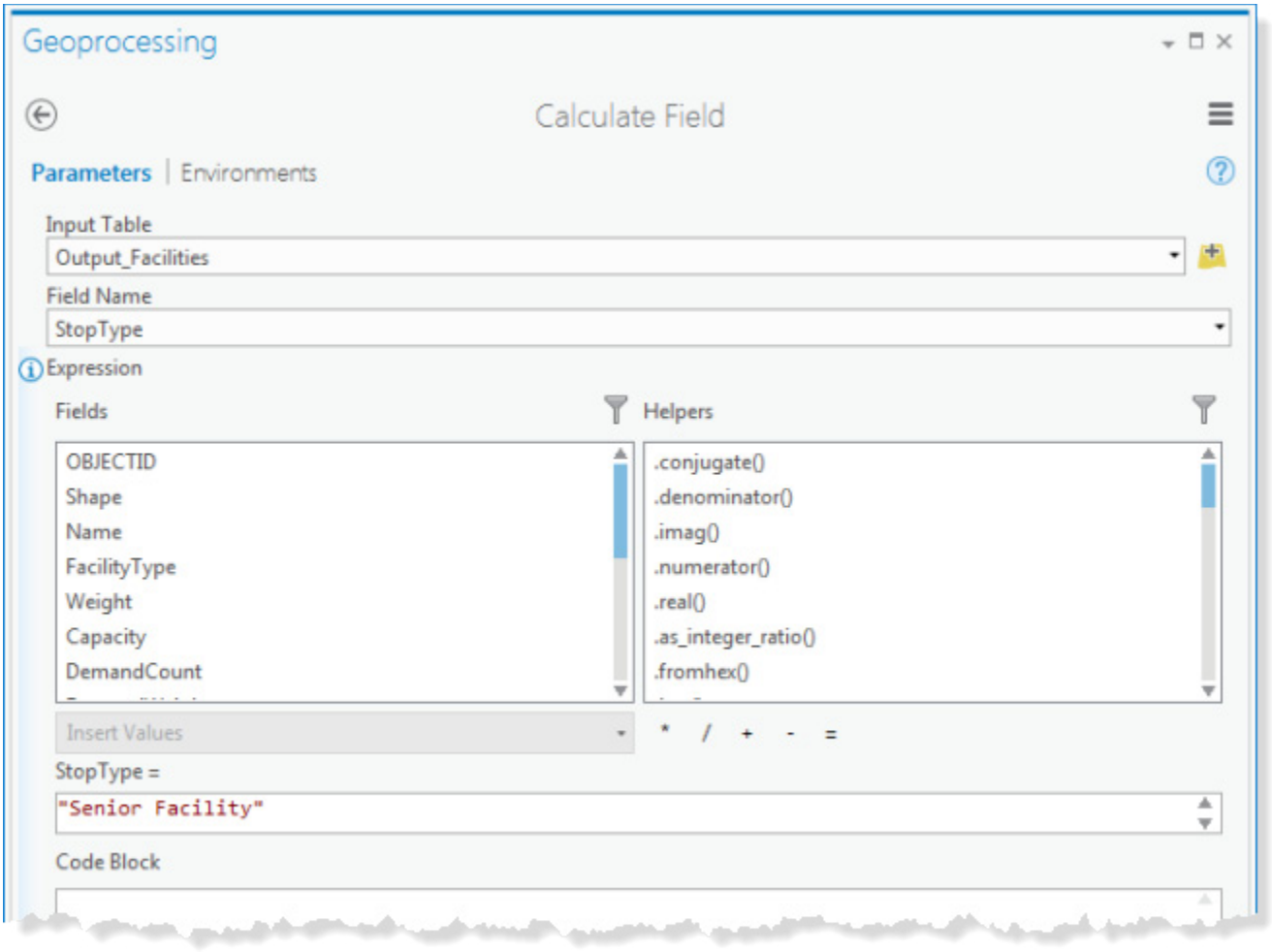
Before creating the two bookmobile routes, the stops need to be merged in a single layer. However, it will be useful going forward to know which stops are senior facilities and which are retail centers. This will make it easier to create the maps of routes and stops. To do this, add a new field named StopType to both output facilities layers.



Next, select the chosen stops in the senior facility layer (chosen stops have a FacilityType value of 3).

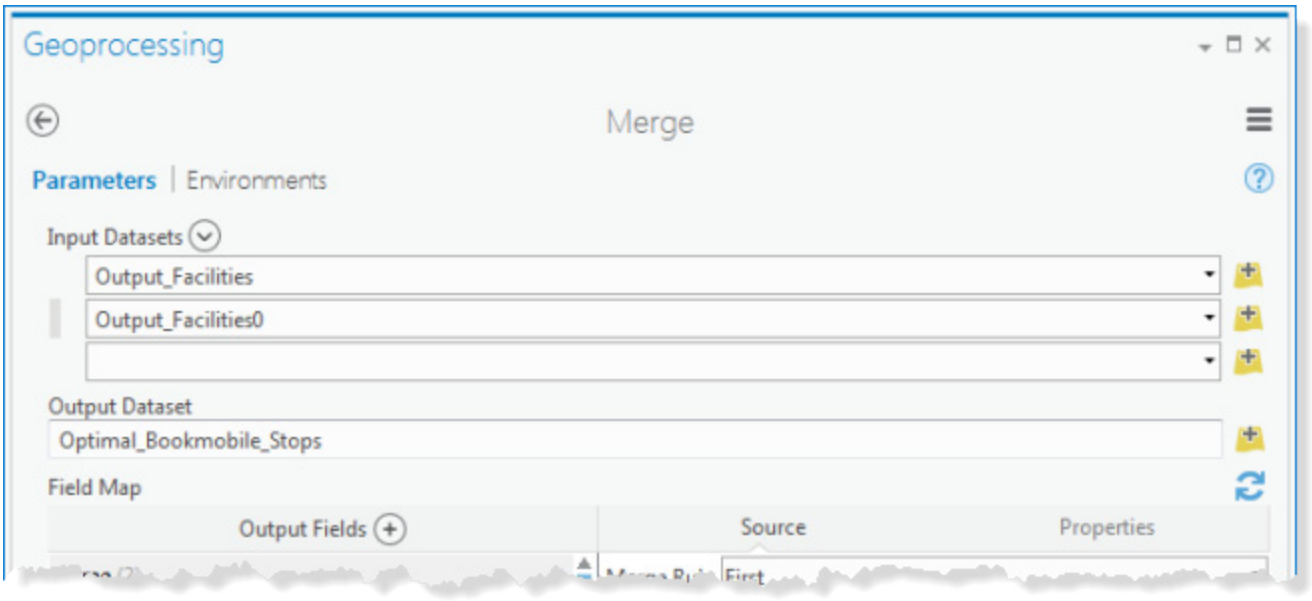


Now assign the value “Senior Facility” to the StopType field.



Do the same for the output facilities layer for the retail centers and malls. First, select the facilities with a FacilityType = 3. Then assign the value “Retail Center” to the StopType Field.

There should be four selected features in each of the two facilities layers. Now merge the layers—only the selected features will be included in the output layer.



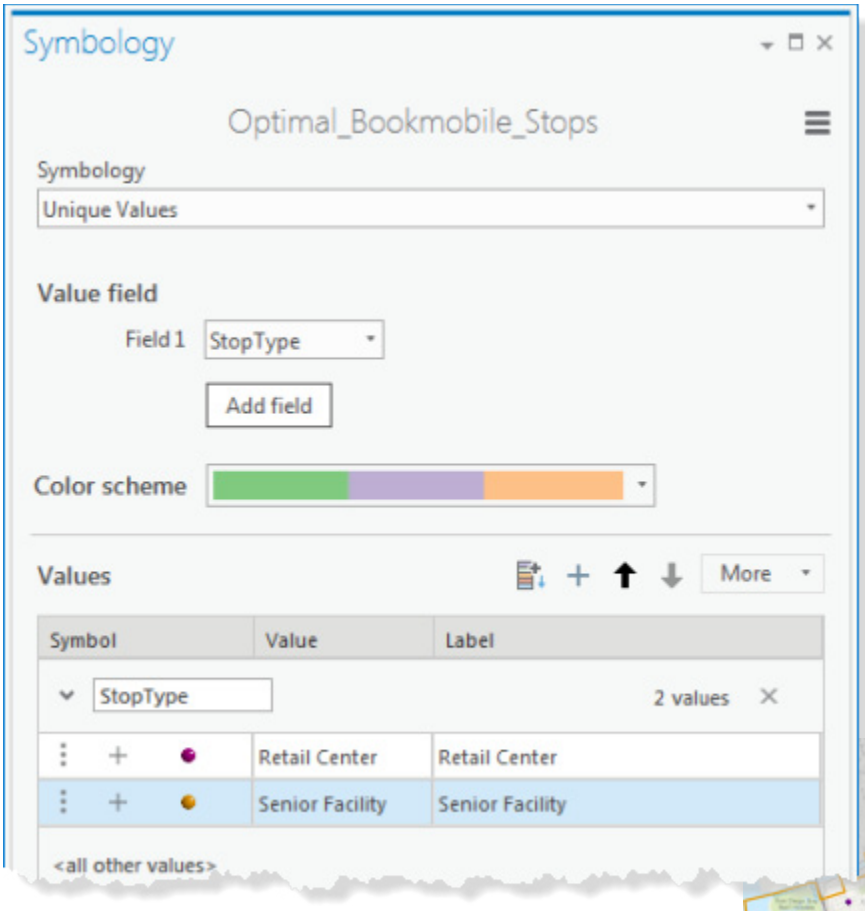
Here is the attribute table for the merged layer, showing the eight stops.

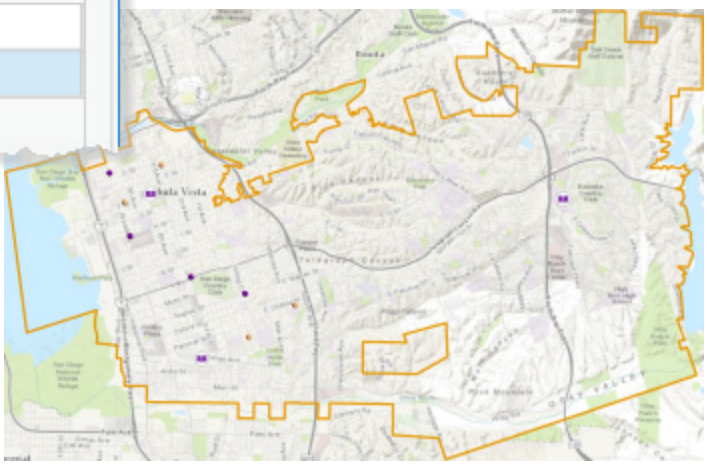
Optimal_Bookmobile_Stops

Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

OBJECTID	Shape	Name	FacilityType	Weight	Capacity	DemandCount	DemandWeight	StopType
1	Point	183 3RD AVE	3	1	<Null>	74	829.102319	Senior Facility
2	Point	553 F ST	3	1	<Null>	93	883.003212	Senior Facility
3	Point	1382 TOBIAS DR	3	1	<Null>	73	720.55621	Senior Facility
4	Point	1280 NOLAN AVENUE	3	1	186	86	490.811926	Senior Facility
5	Point	Wal-Mart Center	3	1	<Null>	73	710.175283	Retail Center
6	Point	Chula Vista Shopping Center	3	1	<Null>	87	606.921904	Retail Center
7	Point	Country Club Shopping Center	3	1	<Null>	92	596.076722	Retail Center
8	Point	Country Club Square Shopping Center	3	1	<Null>	109	729.264681	Retail Center

To create the map of stops by type, change the symbology for the Optimal Bookmobile Stops layer. Specify the Symbology as Unique Values and the Value Field as StopType. If you want, change the format of the individual point symbols by clicking them and specifying their properties.



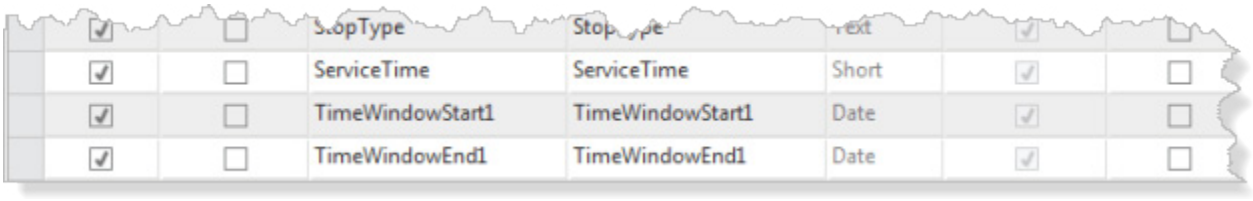


Create the routes and schedules

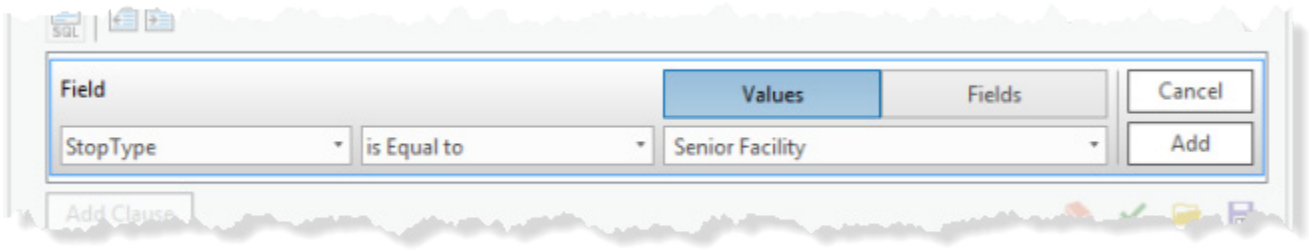
Use the SolveVehicleRoutingProblem tool to group the stops into routes and create the most efficient paths between the stops. The tool requires four inputs—two layers (Orders and Depots) and two standalone tables (Routes and Breaks). You use fields in the layer attribute tables and standalone tables to define the parameters of the routes. Learn more about SolveVehicleRoutingProblem.

Edit the orders layer

In this example the orders correspond to the bookmobile stops. You can add attributes to the orders, such as the duration (ServiceTime) of each stop and the time window within which a stop should be visited. Add the ServiceTime, TimeWindowStart1, and TimeWindowEnd1 fields to the Optimal_Bookmobile_Stops layer. Specify the ServiceTime field as type Short, and the two time window fields as Date. (The field names must be entered as shown, with no underscores or other variations. Otherwise, the SolveVehicleRoutingProblem tool will not recognize them.)



Use Select By Attributes to select the senior facilities (or select them interactively in the table).



Now use Calculate Field to specify a Service Time of 90 minutes.

The senior facility stops are to be visited between 9:00 am and 3:00 pm. To specify the time window for these stops you will need to specify a date as well as a start and end time (the route runs every other Monday, not on a specific date—but SolveVehicleRoutingProblem expects a date). Pick an upcoming Monday. You'll use this same date in all the required date/time fields. Use Calculate Field to enter the TimeWindowStart1 date and time.

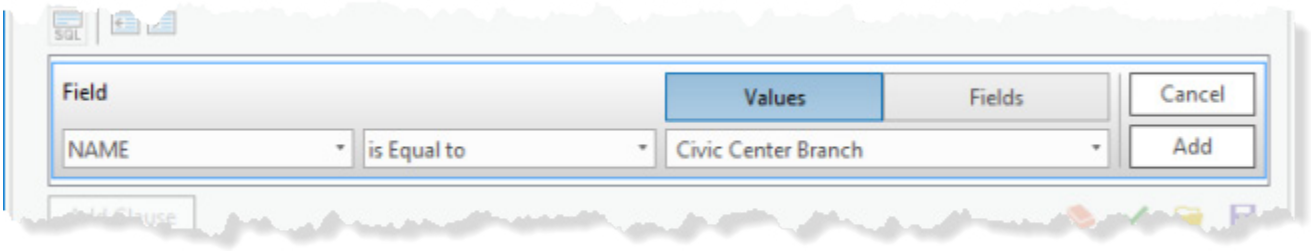
Use Calculate Field again to specify the TimeWindowEnd1 value for the selected stops to be 3:00 pm on the same date.

Switch the selected features in the table so the retail center stops are now selected, then calculate the fields using the same steps as above. The ServiceTime for these stops is 60 minutes, TimeWindowStart1 is 3:00 pm, and TimeWindowEnd1 is 8:00 pm. When you're finished calculating the fields, clear the selection.

meters	StopType	ServiceTime	TimeWindowStart1	TimeWindowEnd1
32088	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM
07147	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM
68097	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM
52093	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM
8965	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM
91738	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM
59192	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM
23811	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM

Create the depots layer

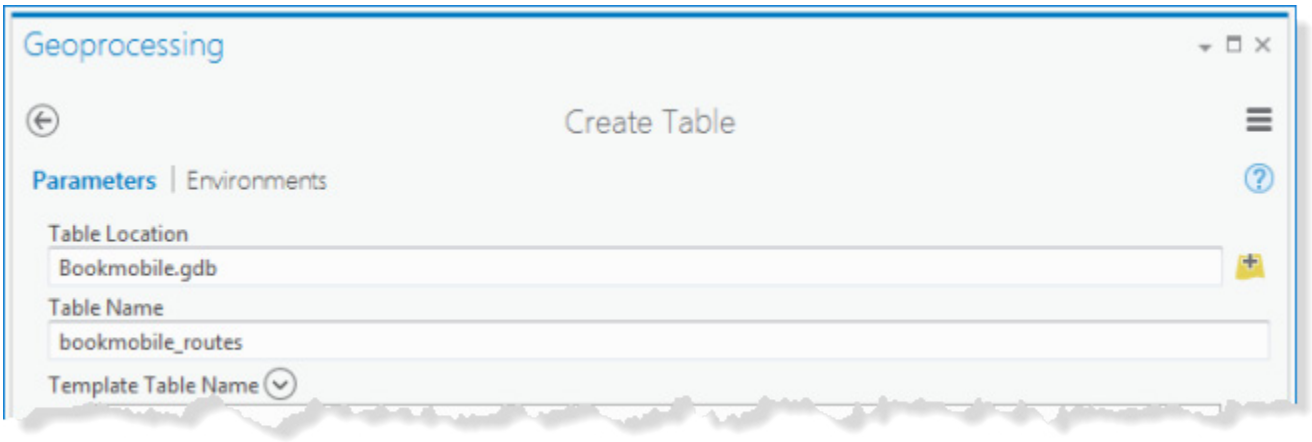
The bookmobile depot for the routes is the Civic Center library branch (this is where the routes will start and end). To create the depot layer, select the Civic Center branch (in the Library layer) and export the selected feature to a new feature class, named bookmobile_depot. No additional attributes are required for the depot.



Create the routes table

The routes table contains most of the information required to create the routes. The table will contain two rows, one for each route. The steps are to create the table, define the necessary fields, and enter the appropriate values for each field.

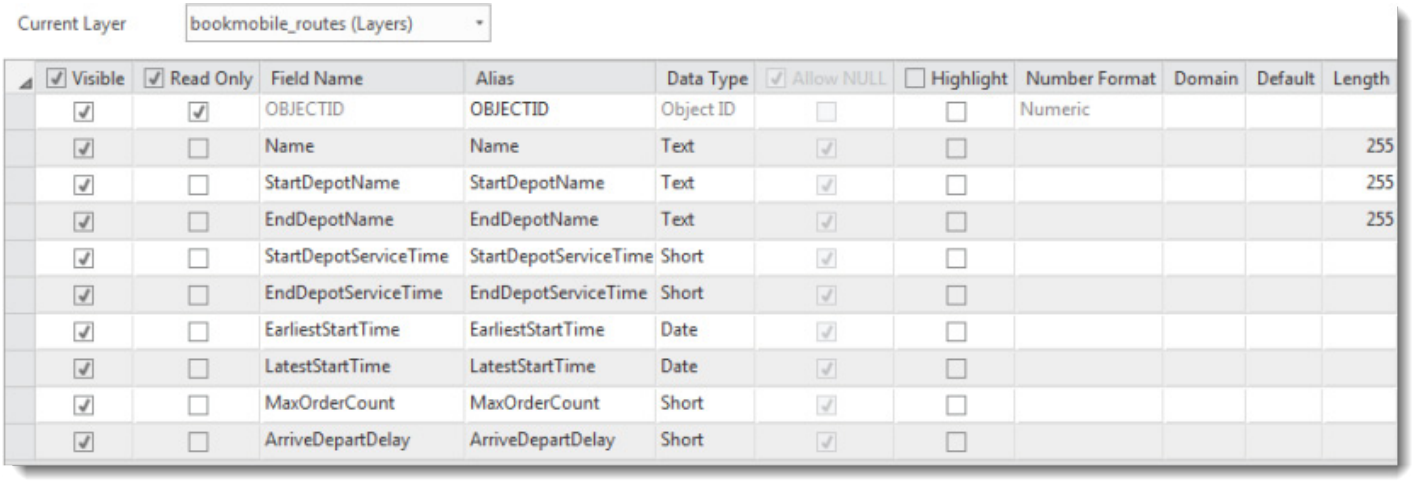
To start, use Create Table to create the empty table.



Here are the parameters for the routes along with the corresponding fields:

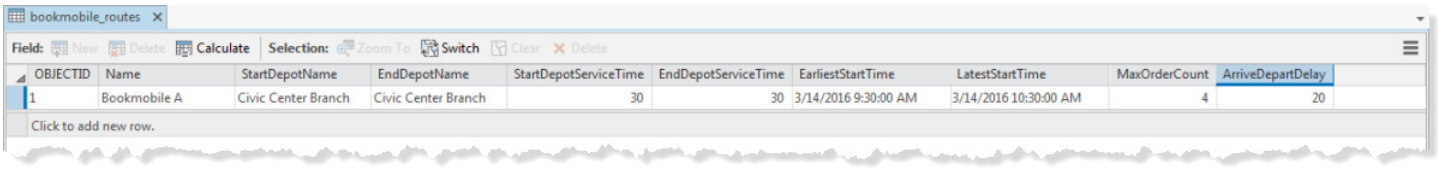
- The routes are named Bookmobile A and Bookmobile B (Name)
- The routes start and end at the Civic Center Branch library (StartDepotName and EndDepotName)
- Allow thirty minutes for loading and unloading at the depot (StartDepotServiceTime and EndDepotServiceTime)
- The routes need to start between 9:30 am and 10:30 am (EarliestStartTime and LatestStartTime)
- Each route should include no more than four stops (MaxOrderCount)
- Include an additional twenty minutes between stops for heavy traffic, reshelving, cleanup and so on (ArriveDepartDelay)

Add the fields as shown below (again, field names must be entered exactly as shown).

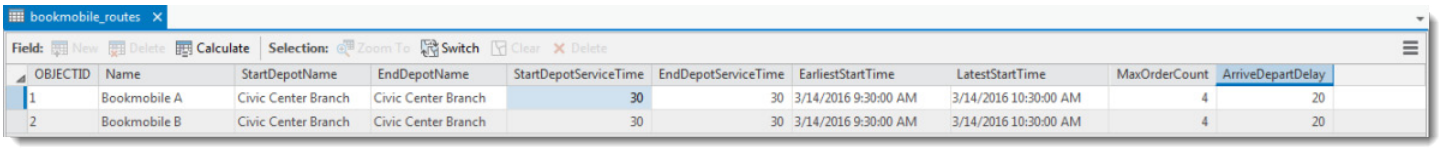


Visible	Read Only	Field Name	Alias	Data Type	Allow NULL	Highlight	Number Format	Domain	Default	Length
☑	☑	OBJECTID	OBJECTID	Object ID	☐	☐	Numeric			
☑	☐	Name	Name	Text	☑	☐				255
☑	☐	StartDepotName	StartDepotName	Text	☑	☐				255
☑	☐	EndDepotName	EndDepotName	Text	☑	☐				255
☑	☐	StartDepotServiceTime	StartDepotServiceTime	Short	☑	☐				
☑	☐	EndDepotServiceTime	EndDepotServiceTime	Short	☑	☐				
☑	☐	EarliestStartTime	EarliestStartTime	Date	☑	☐				
☑	☐	LatestStartTime	LatestStartTime	Date	☑	☐				
☑	☐	MaxOrderCount	MaxOrderCount	Short	☑	☐				
☑	☐	ArriveDepartDelay	ArriveDepartDelay	Short	☑	☐				

Enter the values for the first route by clicking the cells in the first row and typing the appropriate values (the OBJECTID value will be assigned automatically once you press Enter).



Click below the first row to add a new row and enter the appropriate values for the second route in the corresponding cells.



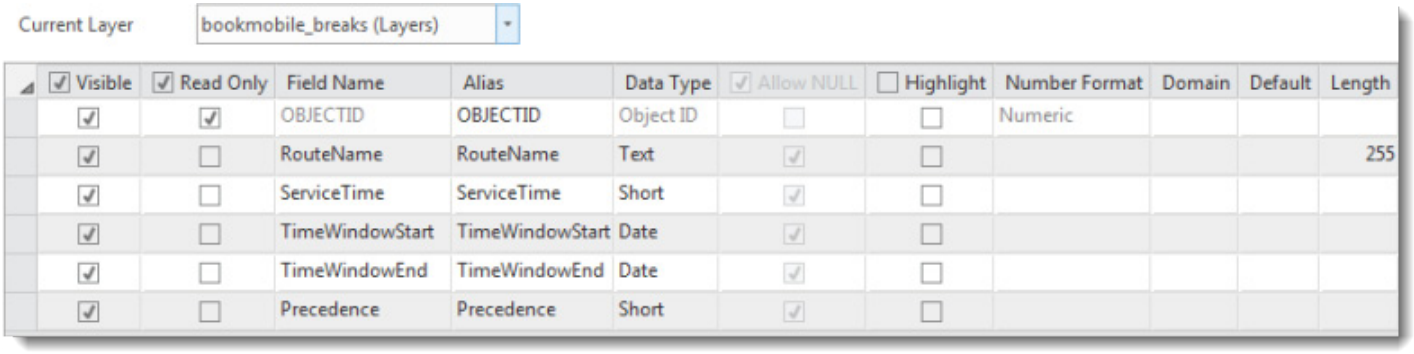
Create the breaks table

The breaks for both routes are contained in a single table. Here are the parameters and fields for the breaks table:

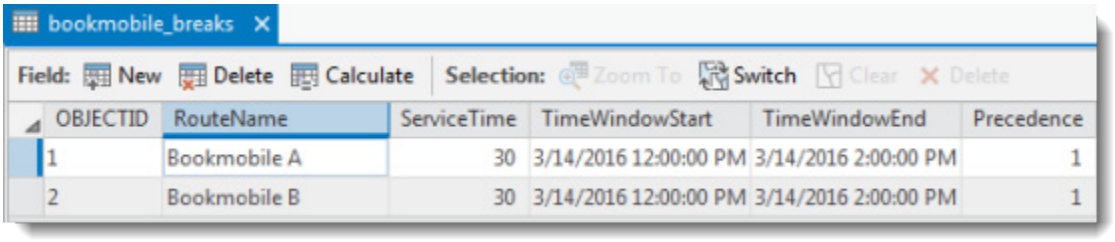
- There is one break for Bookmobile A and one break for Bookmobile B (RouteName)
- Breaks are thirty minutes long (ServiceTime)
- The breaks need to occur between 12 pm and 2 pm (TimeWindowStart and TimeWindowEnd)

In addition, the Precedence field specifies the order of the breaks for each route (it is required, even if there is only one break per route).

To create the breaks table, follow the same process as for the routes table: create the table and add the fields. Name the table bookmobile_breaks (or something similar).

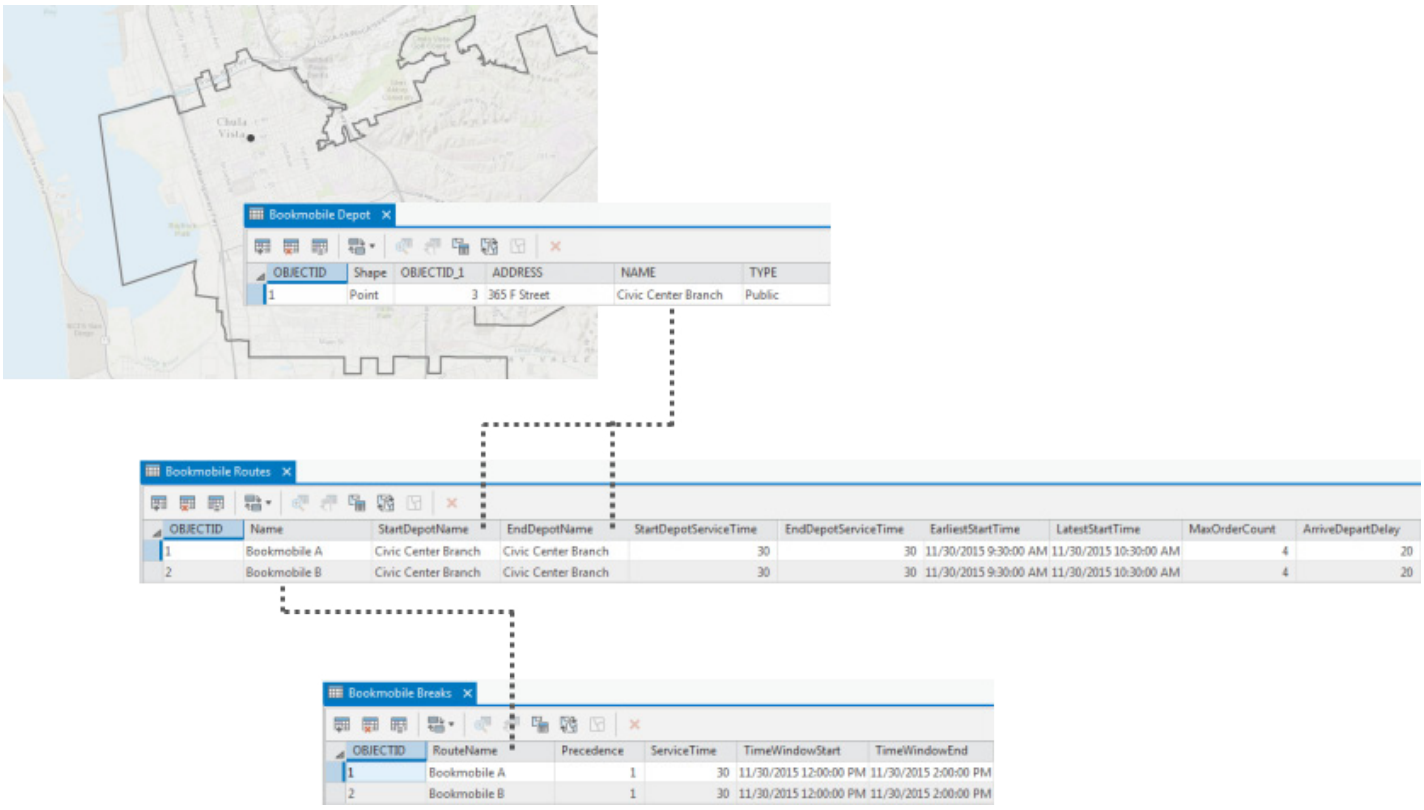


Then enter the values.



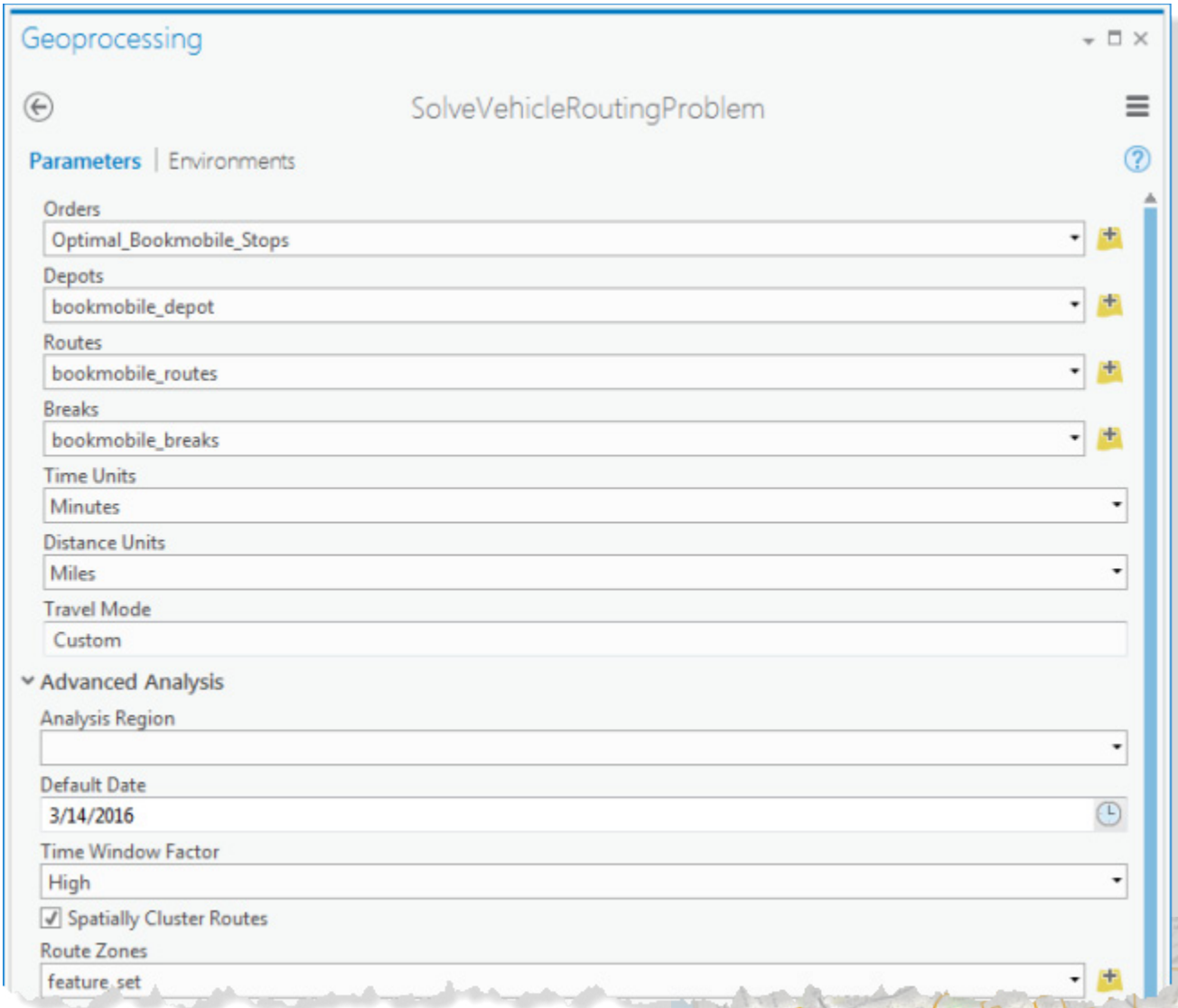
Save all your edits if you haven't already done so.

The RouteName field in the Breaks table references the Name field in the Routes table. Likewise, the StartDepotName and EndDepotName fields in the Routes table reference the Name field in the Depots layer. So before running the tool you will want to check to make sure that the text in these cross-referenced fields matches.

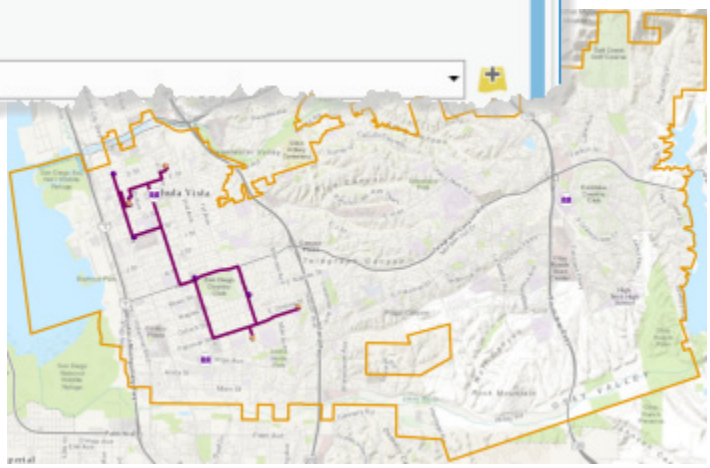


With the layers and tables in place, you can run the SolveVehicleRoutingProblem tool (on the Project pane) to assign stops to routes, place the stops in the most efficient order, and create the shortest paths between them.

Specify the input layers and tables. In the Advanced Analysis section set the Default Date to the same date you specified in the time window fields, and set the Time Window Factor to High (to ensure the stops are visited within the time windows you specified).



The tool assigns stops to routes and creates a table (out_stops) containing the stops, depots, and breaks with their arrive and depart times as well as a layer (out_routes) containing the shortest path between stops. (It also create an output layer called out_directions and a table called out_unassigned_stops. You can ignore these for this workflow. You can also ignore any warning messages generated by the tool.)



out_stops

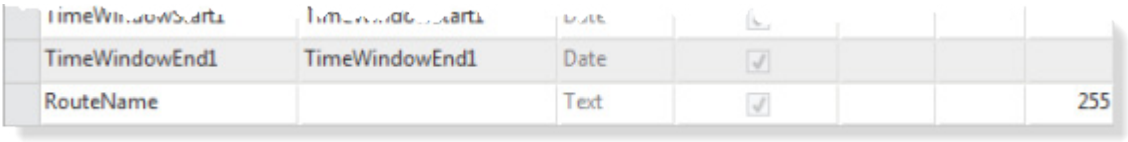
Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

Name	PickupQuantities	DeliveryQuantities	StopType	RouteName	Sequence	FromPrevTravelTime	FromPrevDistance	ArriveCurbApproach	DepartCurbApproach	ArriveTime	DepartTime
183 3RD AVE			0	Bookmobile B	2	23.251403	0.862574	0	0	3/14/2016 10:42:50 AM	3/14/2016 12:12:50 PM
553 F ST			0	Bookmobile B	4	24.942669	1.230827	0	0	3/14/2016 1:07:47 PM	3/14/2016 2:37:47 PM
1382 TOBIAS DR			0	Bookmobile A	2	29.959199	3.648416	0	0	3/14/2016 10:41:49 AM	3/14/2016 12:11:49 PM
1280 NOLAN AVENUE			0	Bookmobile A	4	24.223902	1.14241	0	0	3/14/2016 1:06:03 PM	3/14/2016 2:36:03 PM
Wal-Mart Center			0	Bookmobile B	5	22.220083	0.756024	0	0	3/14/2016 3:00:00 PM	3/14/2016 4:00:00 PM
Chula Vista Shoppin...			0	Bookmobile B	6	23.52893	1.135755	0	0	3/14/2016 4:23:32 PM	3/14/2016 5:23:32 PM
Country Club Shoppi...			0	Bookmobile A	6	22.973824	1.328476	0	0	3/14/2016 4:22:58 PM	3/14/2016 5:22:58 PM
Country Club Square...			0	Bookmobile A	5	23.951573	1.325548	0	0	3/14/2016 3:00:00 PM	3/14/2016 4:00:00 PM
Civic Center Branch	0.000000	0.000000	1	Bookmobile A	1	0	0	0	0	3/14/2016 9:41:52 AM	3/14/2016 10:11:52 AM
Civic Center Branch	0.000000	0.000000	1	Bookmobile A	7	24.734177	1.836067	0	0	3/14/2016 5:47:42 PM	3/14/2016 6:17:42 PM
Civic Center Branch	0.000000	0.000000	1	Bookmobile B	1	0	0	0	0	3/14/2016 9:49:35 AM	3/14/2016 10:19:35 AM
Civic Center Branch	0.000000	0.000000	1	Bookmobile B	7	23.405976	1.10304	0	0	3/14/2016 5:46:56 PM	3/14/2016 6:16:56 PM
Break			2	Bookmobile A	3	0	0	0	0	3/14/2016 12:11:49 PM	3/14/2016 12:41:49 PM
Break			2	Bookmobile B	3	0	0	0	0	3/14/2016 12:12:50 PM	3/14/2016 12:42:50 PM

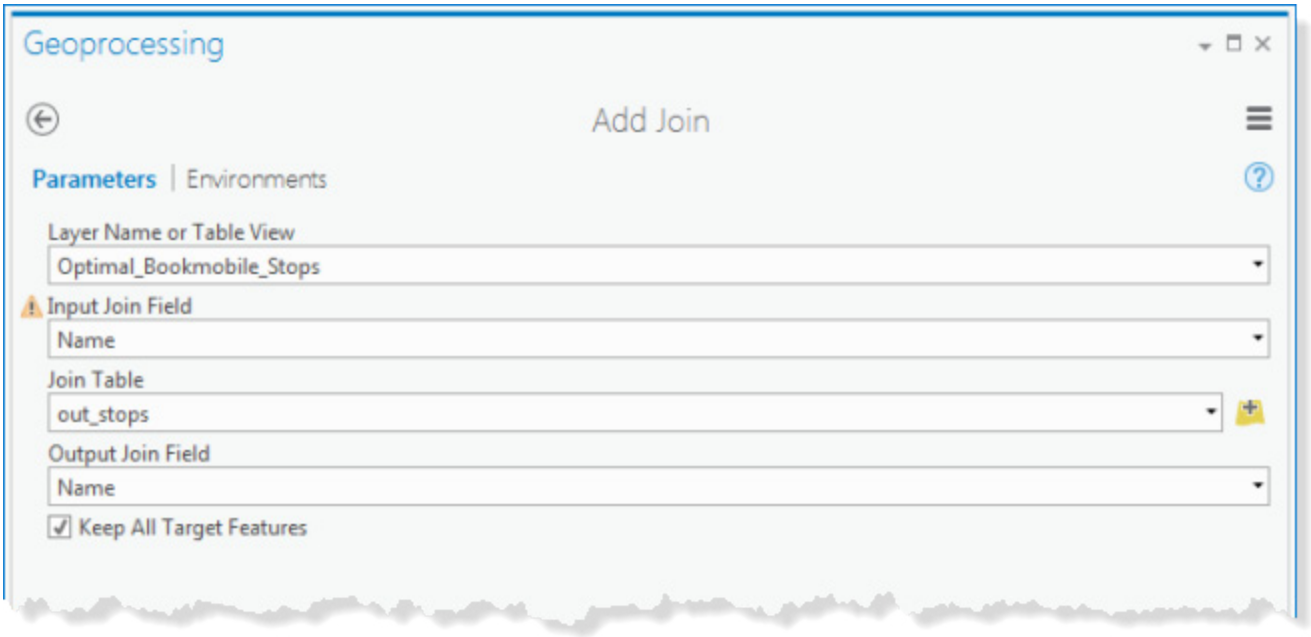
Create the route maps and table

The list of output stops with their assigned routes is stored in the out_stops table. However, the actual stop locations (features) are in the previously created orders layer (Optimal_Bookmobile_Stops). In order to create maps showing which stops are on Route A and which are on Route B you need to assign the route name to the stop features in the Optimal_Bookmobile_Stops layer.

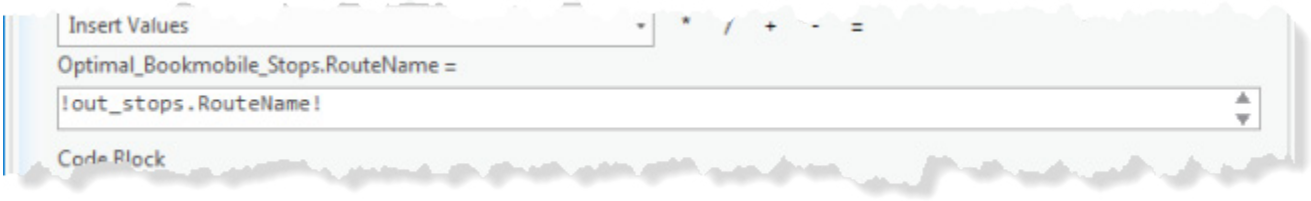
First, add the RouteName field to the Optimal_Bookmobile_Stops attribute table.



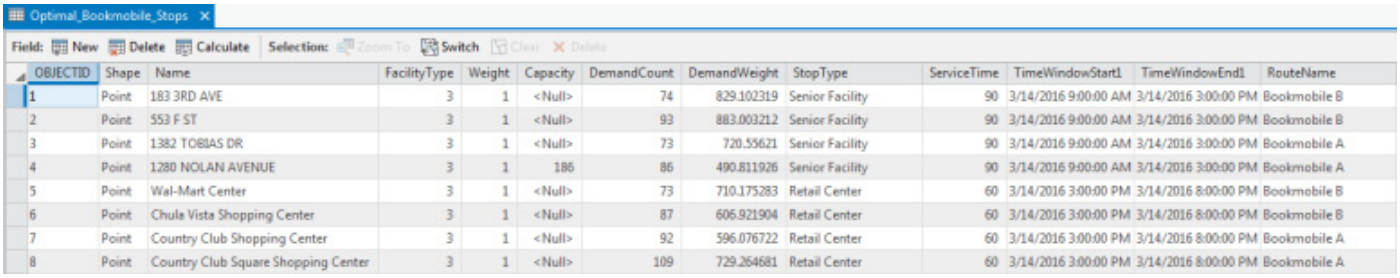
Now join the out_stops table to the Optimal_Bookmobile_Stops layer, using Name as the join field.



Calculate the new RouteName field equal to the joined RouteName field, then remove the join.



Here is how the resulting table looks.



Optimal_Bookmobile_Stops

Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

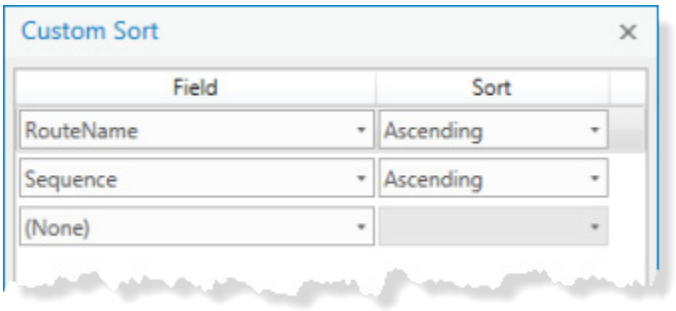
OBJECTID	Shape	Name	FacilityType	Weight	Capacity	DemandCount	DemandWeight	StopType	ServiceTime	TimeWindowStart1	TimeWindowEnd1	RouteName
1	Point	183 3RD AVE	3	1	<Null>	74	829.102319	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile B
2	Point	553 F ST	3	1	<Null>	93	883.003212	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile B
3	Point	1382 TOBIAS DR	3	1	<Null>	73	720.55621	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile A
4	Point	1280 NOLAN AVENUE	3	1	186	86	490.811926	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile A
5	Point	Wal-Mart Center	3	1	<Null>	73	710.175283	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile B
6	Point	Chula Vista Shopping Center	3	1	<Null>	87	606.921904	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile B
7	Point	Country Club Shopping Center	3	1	<Null>	92	596.076722	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile A
8	Point	Country Club Square Shopping Center	3	1	<Null>	109	729.264681	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile A

Now you can select the stops for Bookmobile A, export them to a new layer, and display them on a map.

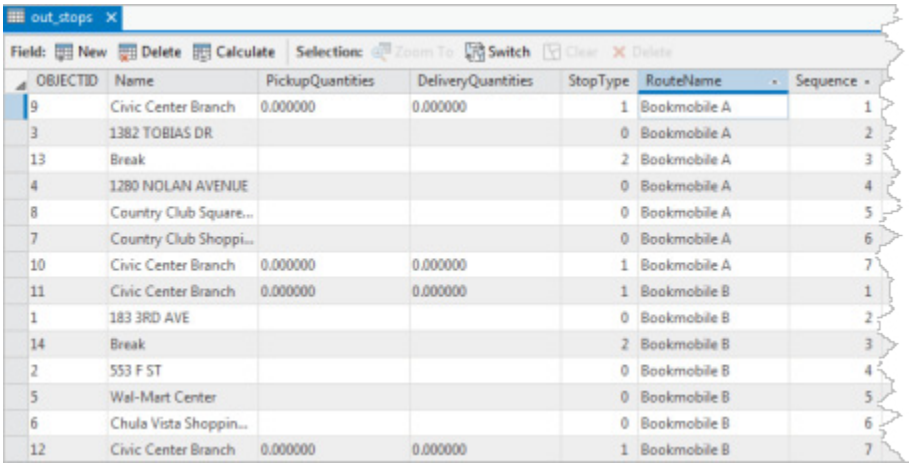
To add the path between the stops to the map, select Bookmobile A in the out_routes layer and export the selected lines.

Do the same to create the map of the stops and path for the Bookmobile B route. You can then change the symbology of the stops, as you did earlier, to show which are senior facilities and which are retail centers.

To show the sequence of stops and breaks for each route, open the out_stops table, right-click the RouteName field, and click Custom Sort. Sort first on RouteName (Ascending) followed by Sequence (Ascending).



The table should look like this.



OBJECTID	Name	PickupQuantities	DeliveryQuantities	StopType	RouteName	Sequence
9	Civic Center Branch	0.000000	0.000000	1	Bookmobile A	1
3	1382 TOBIAS DR			0	Bookmobile A	2
13	Break			2	Bookmobile A	3
4	1280 NOLAN AVENUE			0	Bookmobile A	4
8	Country Club Square...			0	Bookmobile A	5
7	Country Club Shoppi...			0	Bookmobile A	6
10	Civic Center Branch	0.000000	0.000000	1	Bookmobile A	7
11	Civic Center Branch	0.000000	0.000000	1	Bookmobile B	1
1	183 3RD AVE			0	Bookmobile B	2
14	Break			2	Bookmobile B	3
2	553 F ST			0	Bookmobile B	4
5	Wal-Mart Center			0	Bookmobile B	5
6	Chula Vista Shoppin...			0	Bookmobile B	6
12	Civic Center Branch	0.000000	0.000000	1	Bookmobile B	7

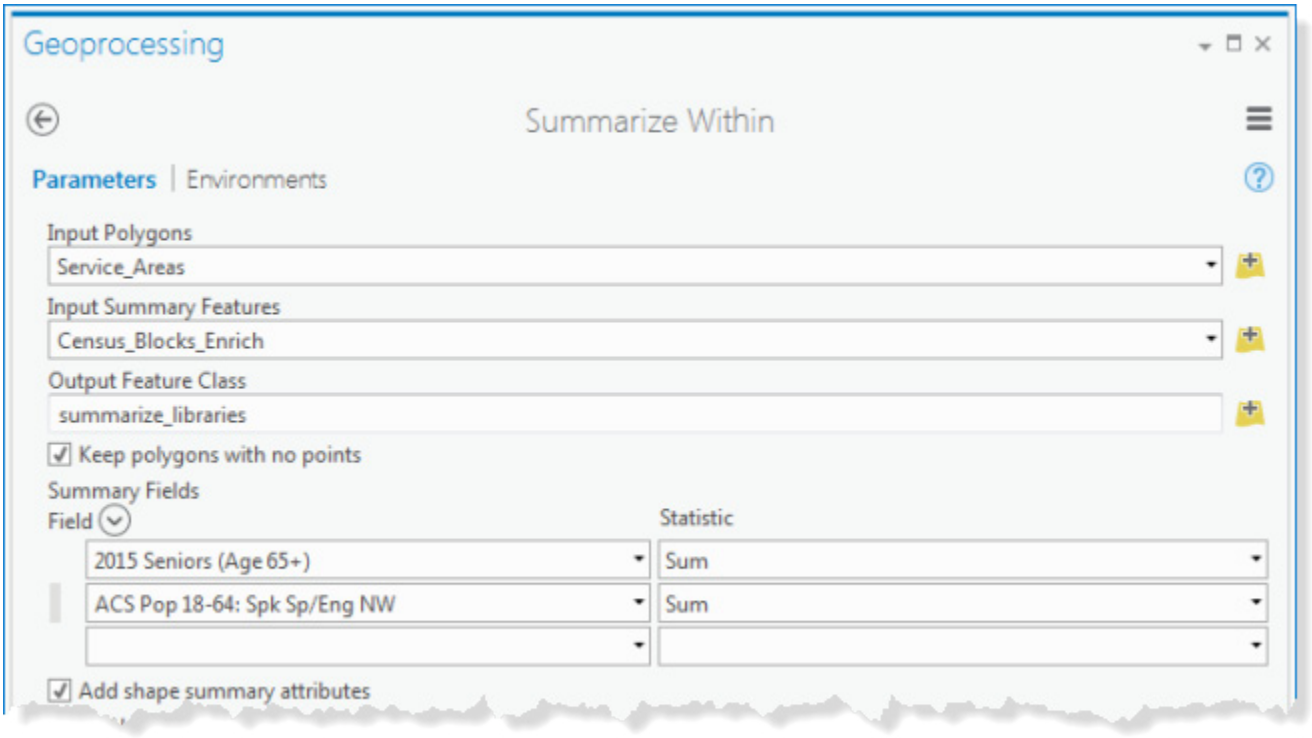
Case Study Section: Garnering political support

- **Find the number of people within a mile of a library branch and within a mile of a branch or bookmobile stop**
- **Create the revised routes including the Veterans Home**
- **Add a second break to the route with five stops and create the updated routes and schedules**

Find the number of people within a mile of a library branch and within a mile of a branch or bookmobile stop

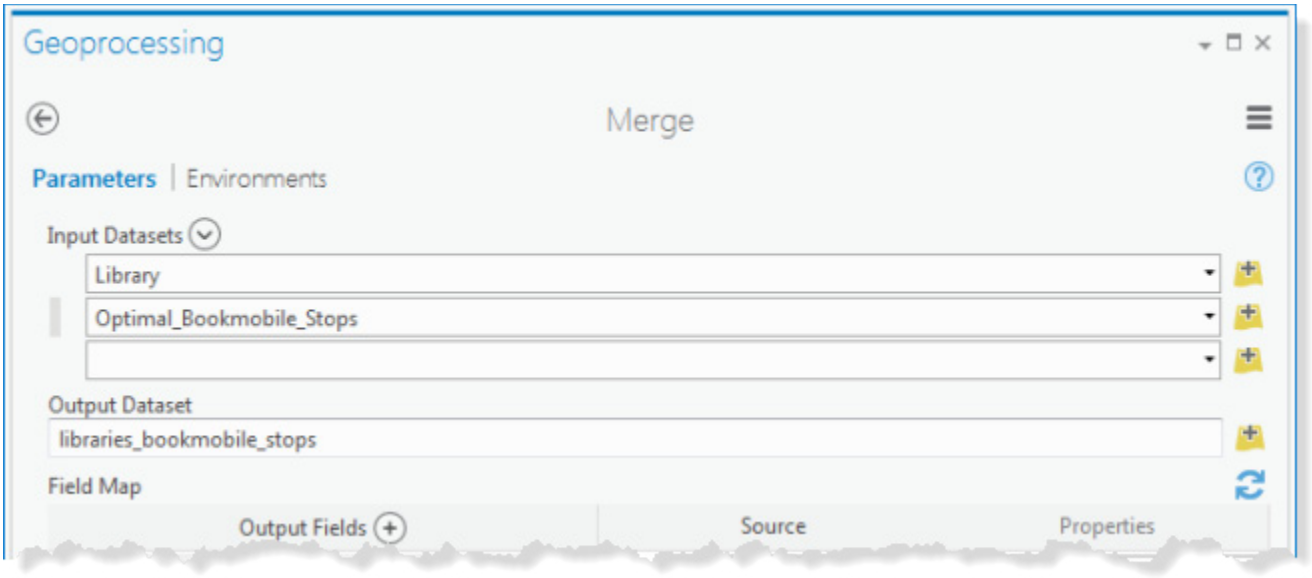
To calculate how many more patrons will be served by the bookmobile versus the library branches alone you'll use two 1-mile service areas—one for the branches alone and one for the combined branches and bookmobile stops. You'll then summarize the number of people in each target population within the service areas.

You created the 1-mile service areas around branch libraries earlier. Use Summarize Within with that layer, along with the enriched census blocks, to find out the number of seniors and Spanish-speaking adults within a mile of a library.

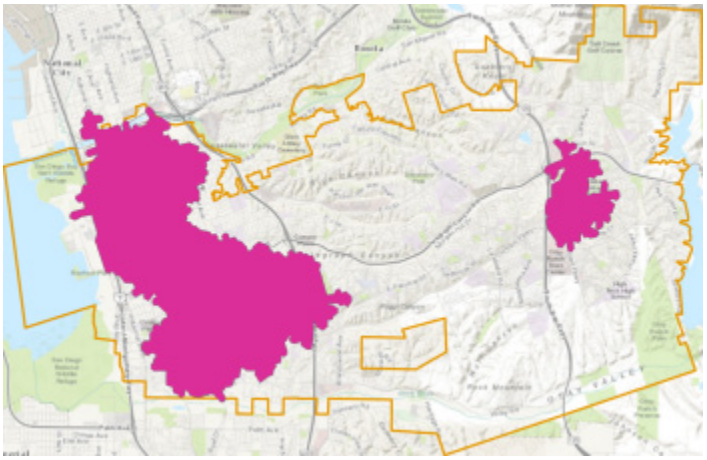


(Even though the summarized field is showing the number of people, it appears as a fractional value. That's because Summarize Within calculates the values based on the portion of each census block that falls within the 1-mile service area polygon.)

Now merge the libraries and the Optimal Bookmobile Stops to create a single layer.



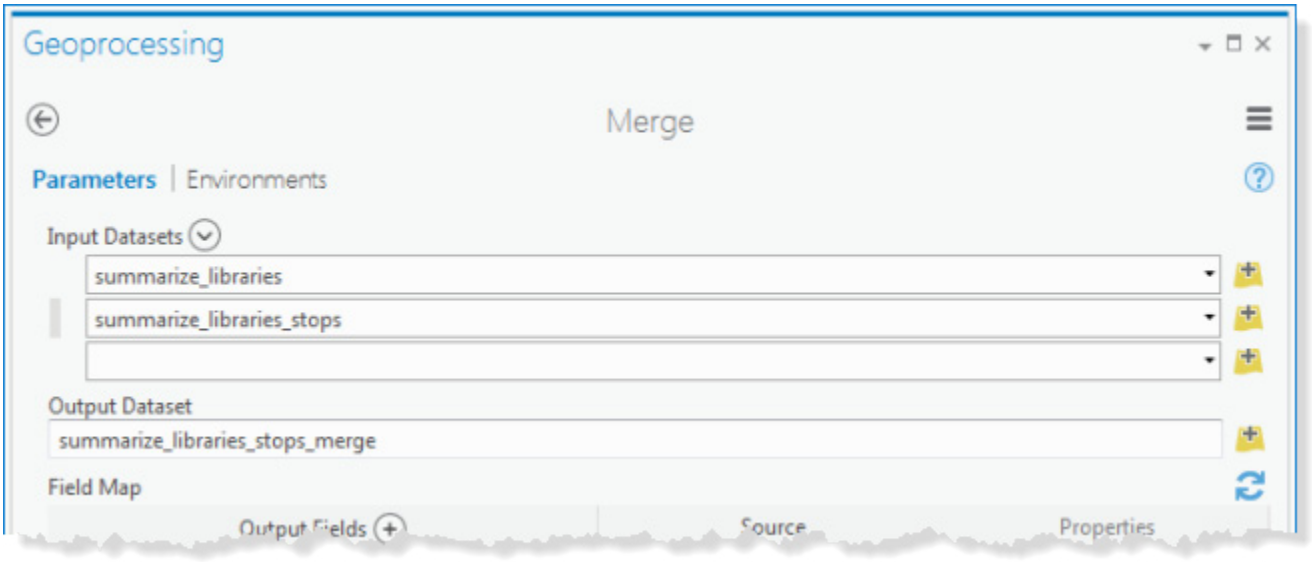
Use the layer of combined libraries and bookmobile stops to create 1-mile service areas. Use the same parameters you used earlier when creating the service areas around library branches. Set the Break Values to 1, the Break Units to Miles, the Travel Direction to Towards Facility (in the Advanced Analysis section), and the Impedance to Travel Distance (in the Custom Travel Mode section). In the Output section, under Polygons for Multiple Facilities, specify Merge by Break Value.



Then run Summarize Within with these service areas to sum the population of seniors and Spanish-speaking adults within a mile of a library branch or bookmobile stop, as shown above.

To create the map of service areas around libraries and bookmobile stops, change the color of the libraries service area to dark blue and the color of the combined libraries and stops service area to light blue. On the map, display the former on top of the latter so that the libraries service area is not obscured.

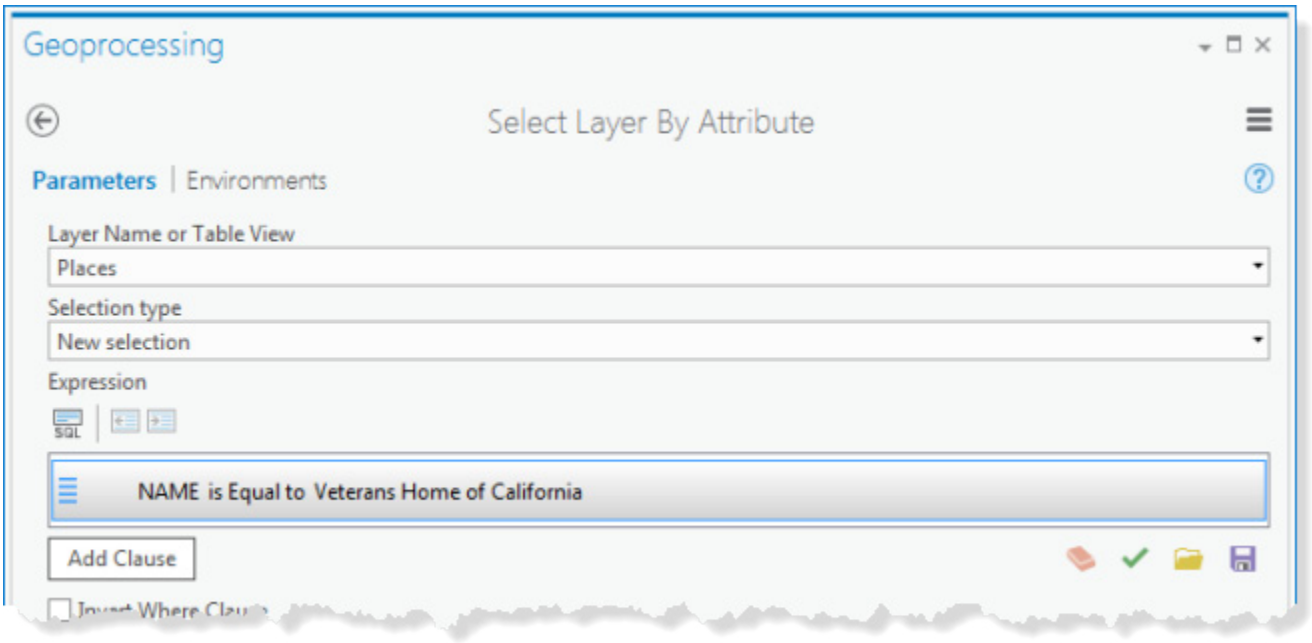
To create the chart comparing the number of people within a mile of a branch to the number within a mile of a branch or bookmobile stop, first merge the two Summarize Within output layers so all the population values are in a single table.

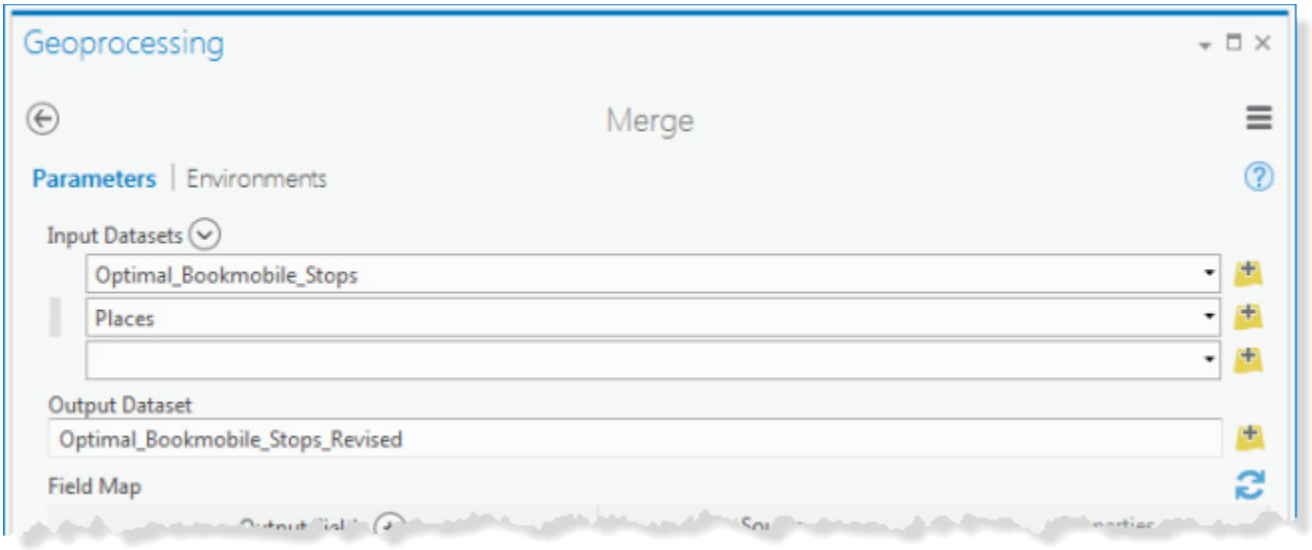


ArcGIS Pro has simple charting capabilities, but as of this writing does not yet support the kind of chart shown in the case study. You'll have to export the table to a dbf file and use Excel (or a similar program) to create a single chart that includes both population categories.

Create the revised routes including the Veterans Home

Select the Veterans Home in the Places layer and merge the Places layer with the layer of existing orders (Optimal_Bookmobile_Stops).





Edit the merged orders to add the values for the Veterans Home. Make the StopType “Senior Facility” and make the ServiceTime and time window values the same as for the senior facility stops. Leave the RouteName field empty—SolveVehicleRoutingProblem will reassign all the stops to create the most efficient solution with the additional stop included.

Optimal_Bookmobile_Stops_Revised

Field: New Delete Calculate Selection: Zoom To Swi

OBJECTID	Shape	Name	FacilityType	StopType	ServiceTime	TimeWindowStart1	TimeWindowEnd1	RouteName
1	Point	183 3RD AVE	3	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile B
2	Point	553 F ST	3	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile B
3	Point	1382 TOBIAS DR	3	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile A
4	Point	1280 NOLAN AVENUE	3	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	Bookmobile A
5	Point	Wal-Mart Center	3	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile B
6	Point	Chula Vista Square Shopping Center	3	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile B
7	Point	Country Club Shopping Center	3	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile A
8	Point	Country Club Square Shopping Center	3	Retail Center	60	3/14/2016 3:00:00 PM	3/14/2016 8:00:00 PM	Bookmobile A
9	Point	Veterans Home of California	<Null>	Senior Facility	90	3/14/2016 9:00:00 AM	3/14/2016 3:00:00 PM	<Null>

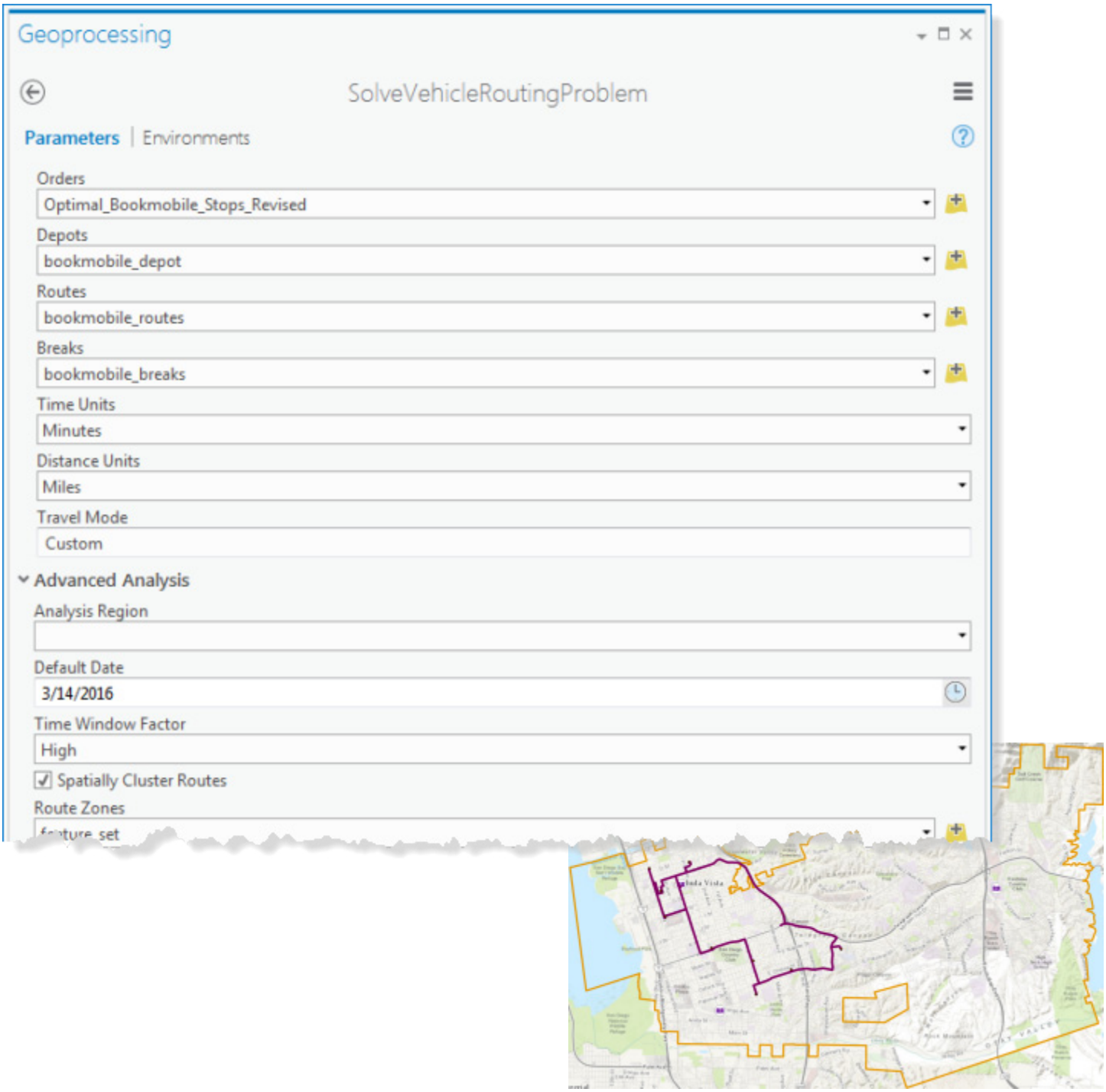
Edit the bookmobile_routes table and increase the MaxOrderCount value to 5 for both routes (to accommodate the additional stop, which will be assigned to one or the other stop).

bookmobile_routes

Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

OBJECTID	Name	StartDepotName	EndDepotName	StartDepotServiceTime	EndDepotServiceTime	EarliestStartTime	LatestStartTime	MaxOrderCount	ArriveDepartDelay
1	Bookmobile A	Civic Center Branch	Civic Center Branch	30	30	3/14/2016 9:30:00 AM	3/14/2016 10:30:00 AM	5	20
2	Bookmobile B	Civic Center Branch	Civic Center Branch	30	30	3/14/2016 9:30:00 AM	3/14/2016 10:30:00 AM	5	20

Run SolveVehicleRoutingProblem to create the updated routes, using the same settings as before (except using the updated orders layer—Optimal_Bookmobile_Stops_Revised).



Add a second break to the route with five stops and create the updated routes and schedules

First, check the newly created out_stops table to see which route contains the five stops (note that the route assignments for stops may have changed once the additional Veterans Home stop was added).

Add a second break to the route that has the five stops by creating a new row in the bookmobile_breaks table. Make the break 30 minutes long with a time window between 5:30 pm and 6:30 pm.

bookmobile_breaks

Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

OBJECTID	RouteName	ServiceTime	TimeWindowStart	TimeWindowEnd	Precedence
1	Bookmobile A	30	3/14/2016 12:00:00 PM	3/14/2016 2:00:00 PM	1
2	Bookmobile B	30	3/14/2016 12:00:00 PM	3/14/2016 2:00:00 PM	1
3	Bookmobile B	30	3/14/2016 5:30:00 PM	3/14/2016 6:30:00 PM	1

When you run SolveVehicleRoutingProblem you can let the tool make the assignment (which is what you've done up to this point) or you can specify which route stops are assigned to.

You want to make sure that the new break is assigned to the route that includes five stops. If you let the tool assign the stops there's the possibility that—with the inclusion of the new break—a stop could be reassigned from the route it's currently on to the other route, which would defeat the purpose of adding the second break to the longer route.

So, you need to make sure that all the stops remain assigned to the same route they are currently assigned to. You do this by including the RouteName field in the orders layer before running the tool (if you don't include it, SolveVehicleRoutingProblem automatically adds the RouteName field to the out_stops table to contain the assigned route, as you've already seen). The RouteName field should already exist in the Optimal_ Bookmobile_Stops_Revised table (you added it earlier to help create the route maps).

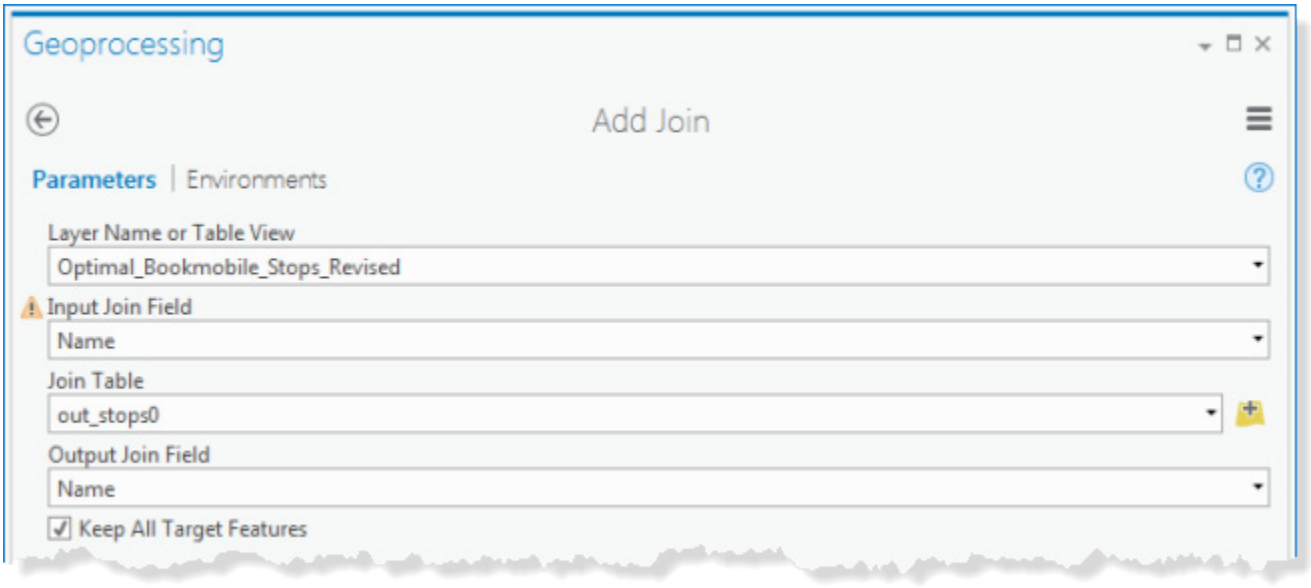
An additional field, AssignmentRule, defines how the tool handles the assignment of stops to routes. A value of 2 specifies that stops should be assigned to the route specified in the RouteName field, but that the sequence of stops can change.

When the AssignmentRule field is used, you also need to include the Sequence field in the orders layer (as with RouteName, Sequence is automatically added to the out_stops layer if it doesn't exist in the orders layer).

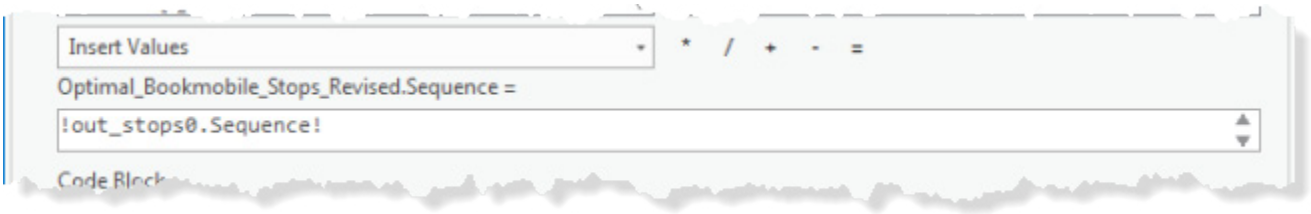
Add the AssignmentRule and Sequence fields to the table.

☑	☐	RouteName	RouteName	Text	☑	☐				255
☑	☐	AssignmentRule	AssignmentRule	Short	☑	☐				
☑	☐	Sequence	Sequence	Short	☑	☐				

Even though the RouteName field already exists in the orders layer, the values may have changed since you last calculated these values so you'll need to update them. (Plus, the Veterans Home has not yet had a route name assigned.) Join the newly created out_stops table to the Optimal_Bookmobile_Stops_Revised layer, using Name as the join field.

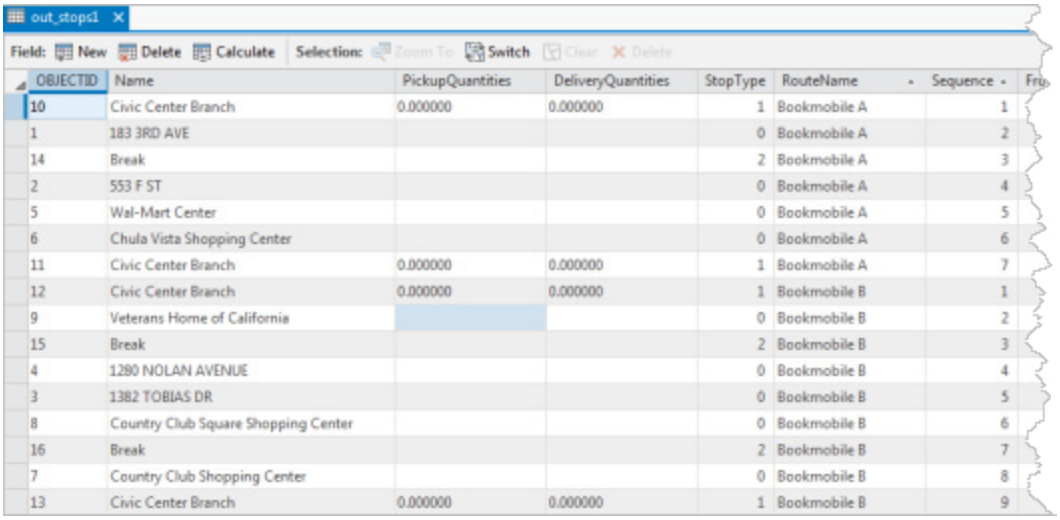


Calculate the RouteName field in the Optimal_Bookmobile_Stops_Revised layer equal to the RouteName field in the out_stops table. Do the same for the Sequence field and then remove the join.



Calculate AssignmentRule equal to 2.

Finally, run SolveVehicleRoutingProblem once again using the settings you used previously to create the final bookmobile routes and schedule.



out_stops1

Field: New Delete Calculate Selection: Zoom To Switch Clear Delete

OBJECTID	Name	PickupQuantities	DeliveryQuantities	StopType	RouteName	Sequence	Fro
10	Civic Center Branch	0.000000	0.000000	1	Bookmobile A	1	
1	183 3RD AVE			0	Bookmobile A	2	
14	Break			2	Bookmobile A	3	
2	553 F ST			0	Bookmobile A	4	
5	Wal-Mart Center			0	Bookmobile A	5	
6	Chula Vista Shopping Center			0	Bookmobile A	6	
11	Civic Center Branch	0.000000	0.000000	1	Bookmobile A	7	
12	Civic Center Branch	0.000000	0.000000	1	Bookmobile B	1	
9	Veterans Home of California			0	Bookmobile B	2	
15	Break			2	Bookmobile B	3	
4	1280 NOLAN AVENUE			0	Bookmobile B	4	
3	1382 TOBIAS DR			0	Bookmobile B	5	
8	Country Club Square Shopping Center			0	Bookmobile B	6	
16	Break			2	Bookmobile B	7	
7	Country Club Shopping Center			0	Bookmobile B	8	
13	Civic Center Branch	0.000000	0.000000	1	Bookmobile B	9	