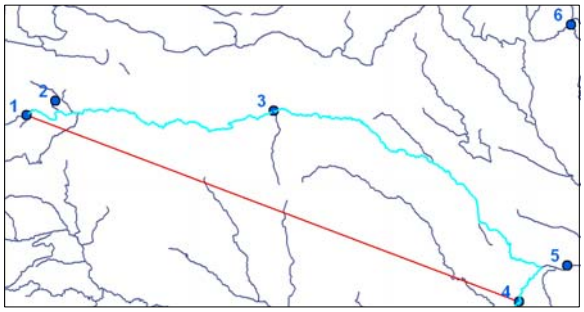
Calculate a Distance Matrix of Locations along River Network



These instructions enable you to measure the length of line segments between points, which is much more useful than simple straight-line distances when you need to work in a network environment such as along water courses, or the more traditional applications on roads and utility features. Using ESRI's ArcGIS 9.x and Microsoft's Access/Excel software perform the following steps to obtain pair-wise distance matrix between all locations:

- Project hydrology skeleton and/or sites to same coordinate system e.g. LCC or UTM
- Perform a spatial join (points to hydrology) to determine maximum distance between points and lines (use this value for snapping tolerance in OD cost matrix solution)
- Create/build network dataset from hydrology using all defaults (accept length as the cost field)
- Create OD cost matrix (see ArcGIS Desktop Help Topic: "Creating an OD cost matrix")
- Export the OD Cost Matrix 'lines' attribute table
- In MS Access/Excel, create a cross-tabulation query/pivot table to organize the data into a true matrix

You need **ArcGIS 9.x** and the **Network Analyst** extension (available from ESRI with paid license).

The hydrology framework data used in this example is 1:1 million scale and available for free from: http://geogratis.gc.ca/downftp/en/Vector/National/Frameworks/hydrology_1M/analytical. NOTE: Examine any hydrology dataset that you use to make sure that rivers are continuous and do not 'break' at the ends of where water body polygons may exist (useless for network analysis and may require extensive editing).

ORIGINAL DATA

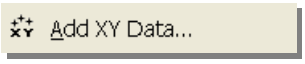
sites.dbf	a dBase table of sample point locations recorded by GPS (this example is projected in NAD83 UTM zone 12)
canadskel_l.shp	a polyline shapefile of continuously connected rivers

CREATED DATA

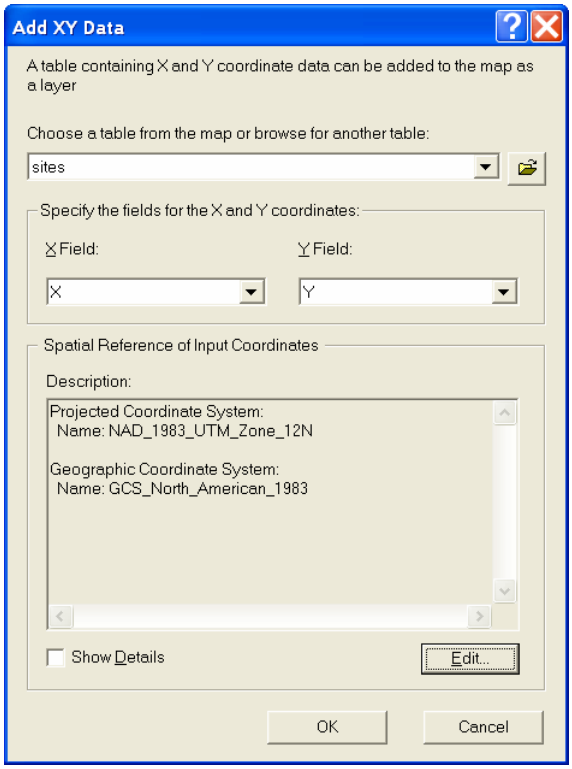
studysites.shp	a point shapefile from the dBase table added as XY Data
studysitesoffset.shp	a point shapefile resulting from a spatial join that calculates distance of points to nearest river
canadskel_l_ND.nd	A network dataset created from the rivers
studysiteslines.shp	a polyline shapefile of the network solution connecting all origin and destination locations with polyline features
sites_distances.dbf	an exported dBase table of distances among all points

Prepare the study data:

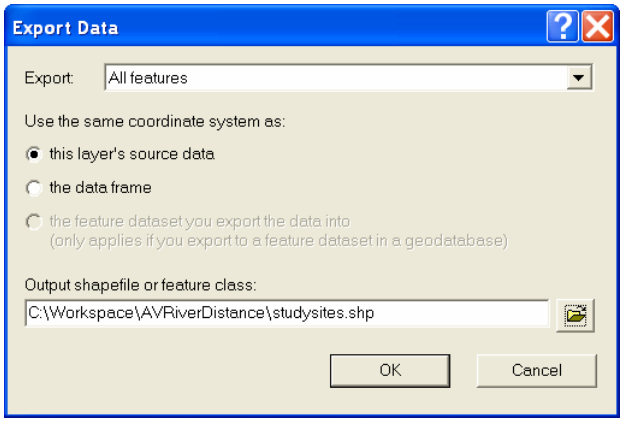
1. Start using ArcMap with a new empty map



2. Choose TOOLS >>> ADD XY DATA



3. Click on the BROWSE button (empty folder icon) and navigate to your working directory; e.g. **C:\Workspace\AVRiverDistance**
4. Select the **sites.dbf** table, and click ADD
5. Specify the appropriate X and Y fields
6. Click on the EDIT button and SELECT the predefined coordinate system that the data were originally collected in; e.g. PROJECTED >>> UTM >>> NAD 1983 >>> NAD_1983_UTM_Zone_12N
7. Click OK
8. In the table of contents, right click on the sites Event layer and choose DATA >>> EXPORT DATA
9. Specify and output name and location for the shapefile and click OK; e.g. **studysites.shp**

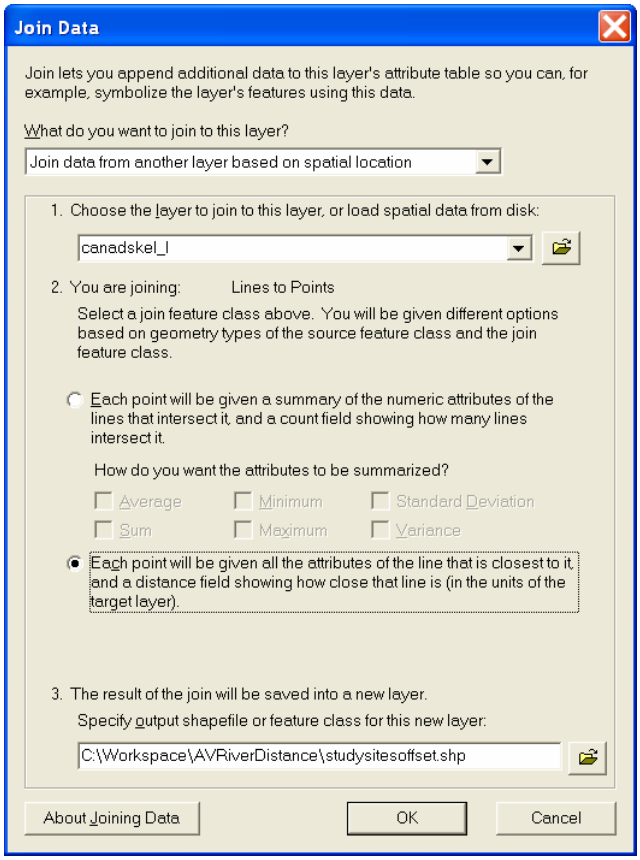


10. Click YES to add the new layer to the map document
11. Right click on **studysites** and choose OPEN ATTRIBUTE TABLE
12. Choose OPTIONS >>> ADD FIELD
13. In the ADD FIELD dialog box, specify:
    - Name: **ID**
    - Type: **Short Integer**
    - Precision: default
14. Click OK
15. Right click on the new ID heading and choose CALCULATE VALUES
16. In the Field Calculator expression box, enter **[FID] + 1** and click OK

This new unique ID field is important for joining back attributes later!!! The network analysis processes the data in the order the features are spatially encountered, which is according to the [FID], but renames each location by incrementing it by one. Use this to link back to your original data to keep track of which site is which.

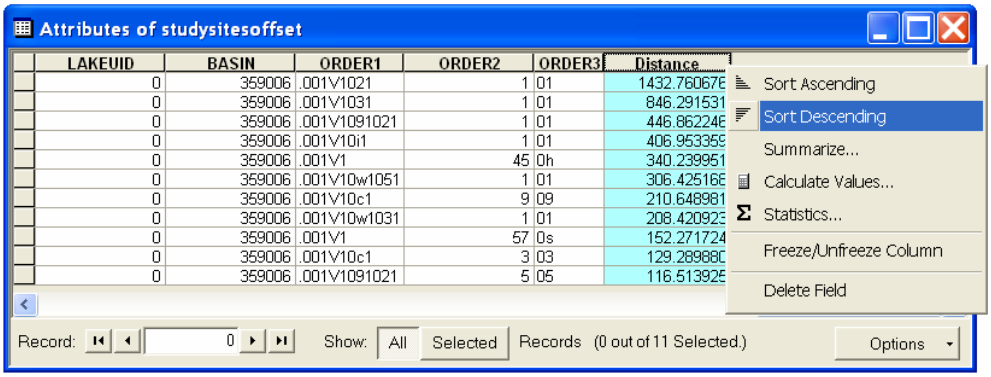
17. Remove the sites Event layer – right click and choose REMOVE
18. Click the ADD DATA button and select **canadskel_l.shp** to add it to the map document

This data layer is originally in a geographic coordinate system, but is reprojected on-the-fly to the coordinate system defined by your sites point data. To effectively compute distance, <u>all data layers will need to be in a projected coordinate system</u> (distance in decimal degrees is not useful). Therefore, if your study sites were originally in Longitude/Latitude, then you will need to project to UTM or Lambert Conformal Conic, or other projection, before proceeding with these instructions. Contact the GIS Technologist if you need help in this.



19. Right click on **studysites** and choose JOINS AND RELATES >>> JOIN…
20. Choose to 'Join data from another layer based on spatial location'
21. At step 1, select **canadskel_l**
22. At step 2, select 'Each point will be given all the attributes of the line that is closest to it, and a **distance** field showing how close that line is (in the units of the target layer).'
23. At step 3, specify an output name and location; e.g. **studysitesoffset.shp**
24. Click OK

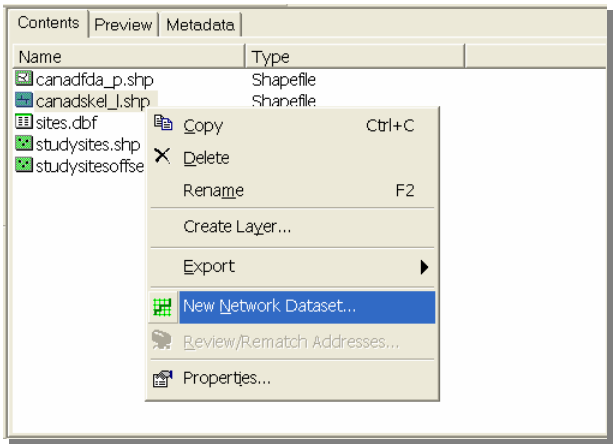
This output shapefile is spatially identical to the input, but has the useful attribute DISTANCE, that indicates the maximum distance of any point to the river layer. Use this value to snap the points to the lines when analyzing the network (it virtually 'moves' the points so that they lie exactly on the line locations – because GPS coordinate collection methods are never exact). Also, note that the distance units are calculated in the coordinate system of the target point layer – again, it is very important that you are working in a projected coordinate system such as UTM or Lambert Conformal Conic.



25. Right click on the **studysitesoffset** layer and choose OPEN ATTRIBUTE TABLE

26. Scroll all the way to the end of the fields to view the DISTANCE field
27. Right click on the DISTANCE heading and choose SORT DESCENDING – make note of the highest value – this is the value you will need to use in the network analysis; e.g. 1432.76, or rounded up to an even **2000 meters** (because the map units of the target points are in meters!)
28. Remove the studysitesoffset layer – right click and choose REMOVE

Create and build the network dataset:



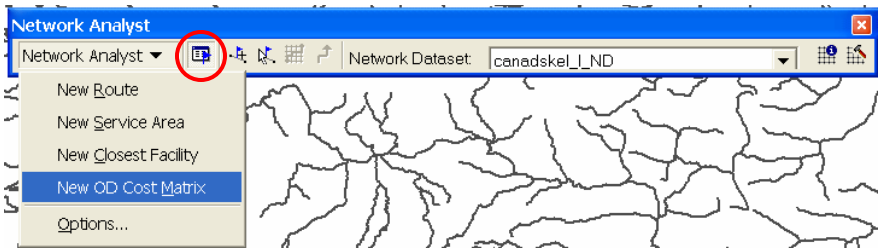
1. Open ArcCatalog and navigate to your working directory; e.g. C:\Workspace\AVRiverDistance
2. Choose TOOLS >>> EXTENSIONS and make sure there is a check beside NETWORK ANALYST
3. In the Contents View, right click on **canadskel_l.shp** and choose NEW NETWORK DATASET
4. Accept all defaults by clicking NEXT in each wizard dialog box
5. Click <u>YES to add a cost attribute based on the shape length</u>
6. Continue clicking NEXT until you can click FINISH
7. Click <u>YES to build the network dataset</u> – this will take several minutes!

Read all about creating a network dataset, and the various parameters and options, in the ArcGIS Desktop Help topic "Creating a network dataset."

8. Close ArcCatalog when finished

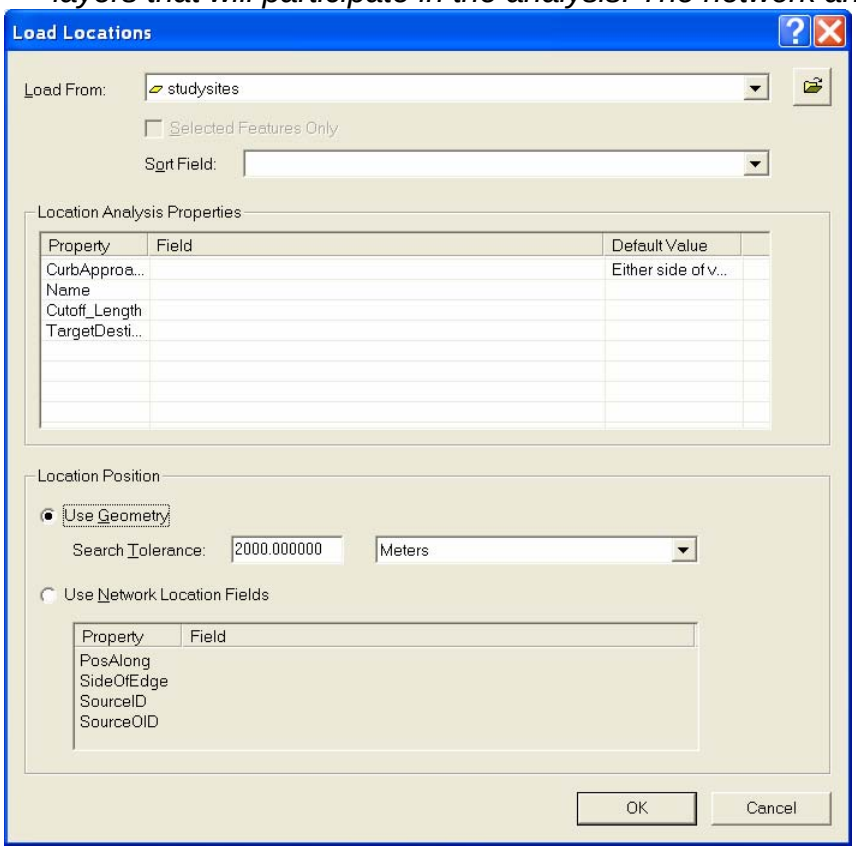
Solve the network for an Origin-Destination (OD) cost matrix:

1. Back in ArcMap, choose TOOLS >>> EXTENSIONS and make sure there is a check beside NETWORK ANALYST
2. Choose VIEW >>> TOOLBARS and make sure there is a check beside NETWORK ANALYST
3. Click the ADD DATA button and add the **canadskel_l_ND.nd** network dataset
4. Click NO to add only the edges
5. In the NETWORK ANALYST toolbar, click on the Show/Hide Network Analyst Window to show it – dock it anywhere you wish in the map document

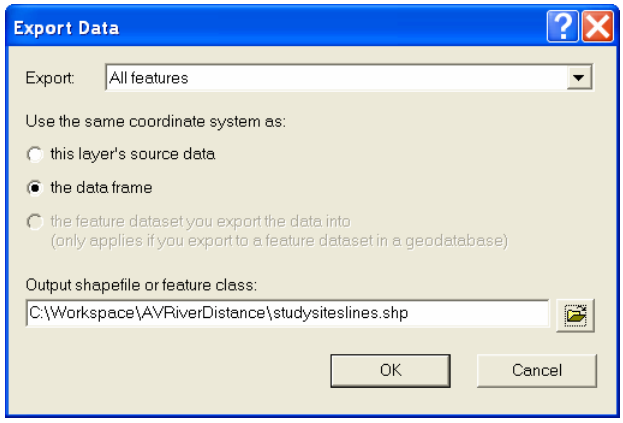


6. Choose NETWORK ANALYST >>> CREATE NEW OD COST DISTANCE MATRIX

The table of contents automatically sets up the symbology for the categories of layers that will participate in the analysis. The network analysis window shows the available options to set. See the ArcGIS Desktop Help topic "Creating an OD cost matrix" for more details.



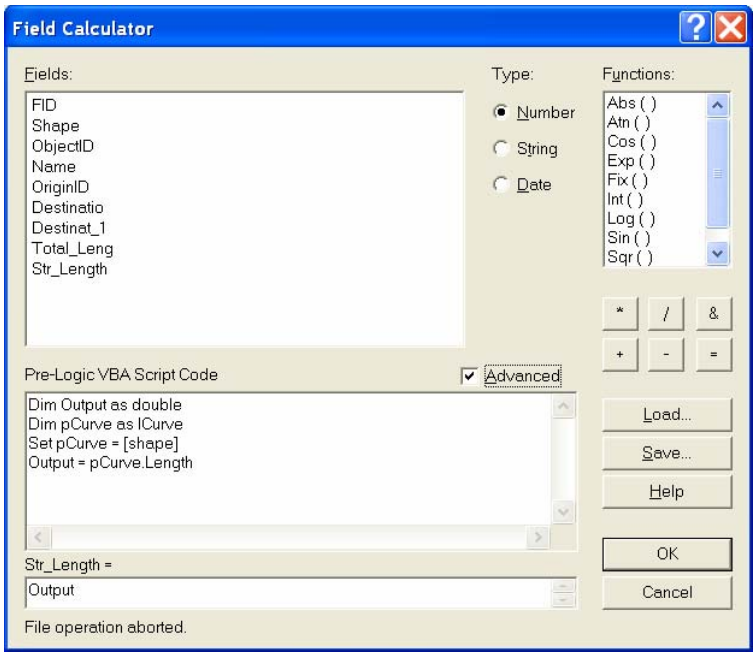
7. In the network analyst window, right click on ORIGINS and choose LOAD LOCATIONS…
   - Load from: **studysites.shp**
   - In the Location Position frame, specify to Use geometry with a SEARCH TOLERANCE of **2000** meters (the value you determined from the spatial join)
   - Click OK
8. In the network analyst window, right click on DESTINATIONS and choose LOAD LOCATIONS…; e.g. **studysites.shp** and use the same search tolerance as above
9. In the table of contents, right click on the OD Cost Matrix layer name and choose PROPERTIES
10. Optionally, in the ANALYSIS SETTINGS tab, specify any settings – *this is normally applicable to transportation and utility type networks, so ignore this step*



11. Click the SOLVE button

Distances between all origins and destinations are calculated and graphically displayed by their straight-line connections. The number of lines should total to # origin locations X # destination locations, if every possible pair-wise distance was solved for.

12. In the table of contents, right click on the **Lines** layer and choose DATA >>> EXPORT DATA
13. Export the data using the same coordinate system as the data frame, specify an output name; e.g. **studysiteslines.shp**, and click OK
14. Right click on **studysiteslines** and choose OPEN ATTRIBUTE TABLE
15. Click on the OPTIONS button and choose ADD FIELD
16. In the ADD FIELD dialog box, specify:
    - Name: Str_Length
    - Type: Double
    - Precision: 20
    - Scale: 2
17. Click OK



18. Right click on the new heading STR_LENGTH and choose CALCULATE VALUES
19. Check the ADVANCED box
20. In the Pre-Logic Script Code window, enter the following:

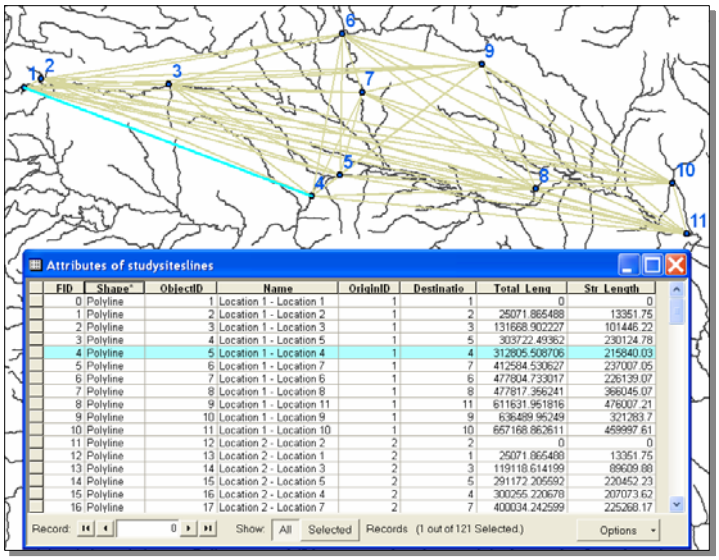
```
Dim Output as double
Dim pCurve as ICurve
Set pCurve = [shape]
Output = pCurve.Length
```

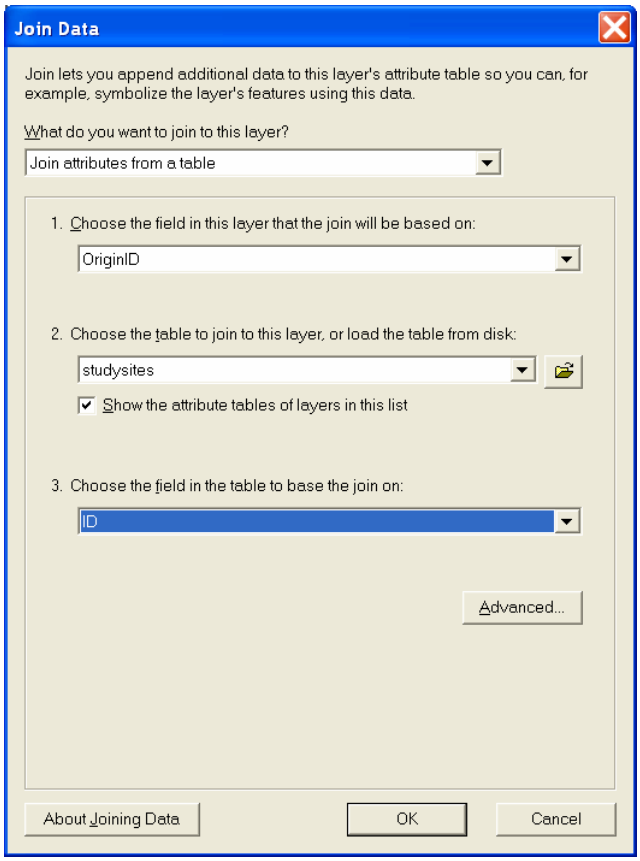
21. In the bottom box, enter the word **`Output`**

To learn more about this calculation, click on the HELP button.

22. Click OK

There are now two fields referring to distance between site locations in the attribute table. The first field, TOTAL_LENG, was calculated along the river network, and the second field, STR_LENGTH, was calculated as the straight-line connections from each origin to destination. You may wish to join the attributes from the original studysites layer to make identification of each location easier.





23. In the table of contents, right click on the **studysiteslines** layer and choose JOINS AND RELATES >>> JOIN…
24. Specify that you want to 'Join attributes from a table.'
25. At step 1, choose the **OriginID** field
26. At step 2, choose the **studysites** table
27. At step 3, choose the **ID** field
28. Click OK

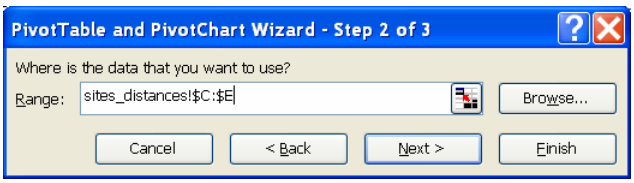
In the studysiteslines attribute table, you will see the appended fields from the original point data. This attribute table is also what you may export for further statistical analysis.

29. Click OPTIONS >>> EXPORT
30. Specify an output name and export all records; e.g. **sites_distances.dbf**
31. Click OK
32. Save the map document and then close ArcMap when finished

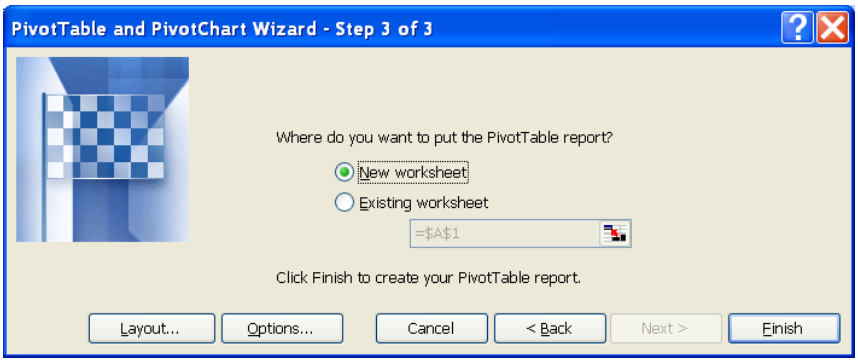
Import the table for use in MS Excel/Access:

The sites_distances.dbf table has a record for each and every pair-wise distance. To set this up in matrix form, import the table into a spreadsheet or database application. To create a cross-tabulation query in MS Access for the distance matrix, see page 3 in:
http://www.biology.ualberta.ca/facilities/gis/uploads/instructions/AVErrorMatrix.pdf.
The following explains how to create the related pivot table in MS Excel.

1. Open MS Excel
2. Choose FILE >>> OPEN
3. Navigate to your working directory and select Files of type: dBase Files
4. Select the **sites_distances.dbf** table and click OPEN
5. Choose FILE >>> SAVE AS
6. Select Files of type: Microsoft Excel Workbook
7. Specify a new name; e.g. **sites_matrix.xls** and click SAVE
8. Choose DATA >>> PIVOTTABLE AND PIVOTCHART REPORT
9. In step 1, select Microsoft Excel list or database and PivotTable (i.e. the defaults for this step); click NEXT



10. In step 2, click on the range button and highlight the columns to use (i.e. the Origin, Destination, and Total_Leng columns); click NEXT

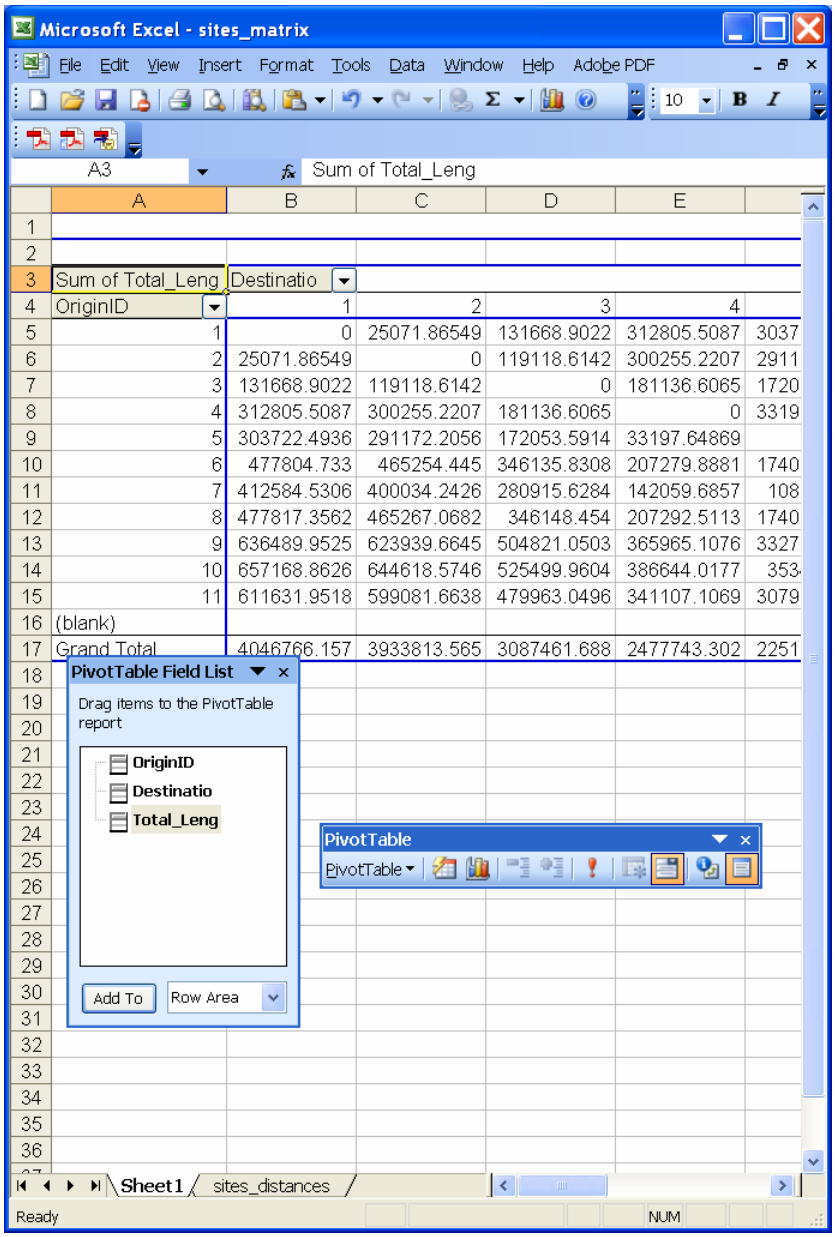


11. In step 3, select to put the PivotTable report in a New Worksheet; click FINISH
12. In the new worksheet, find the PivotTable Field List
13. Click and drag ORIGINID to the DROP ROW FIELDS HERE area
14. Click and drag DESTINATIO to the DROP COLUMN FIELDS HERE area
15. Click and drag TOTAL_LENG to the DROP DATA ITEMS HERE area

16. Double click where it says ‘Count of Total_Leng’ and choose to Summarize by SUM (Average, Min, and Max will work, too)

You now have a distance matrix showing the origin IDs and their lengths to destination IDs. You may opt to repeat the pivot table procedure using the Str_Length data in a new distance matrix.

17. Save the .xls file



	A	B	C	D	E	
3	Sum of Total_Leng	Destinatio				
4	OriginID	1	2	3	4	
5	1	0	25071.86549	131668.9022	312805.5087	3037
6	2	25071.86549	0	119118.6142	300255.2207	2911
7	3	131668.9022	119118.6142	0	181136.6065	1720
8	4	312805.5087	300255.2207	181136.6065	0	3319
9	5	303722.4936	291172.2056	172053.5914	33197.64869	
10	6	477804.733	465254.445	346135.8308	207279.8881	1740
11	7	412584.5306	400034.2426	280915.6284	142059.6857	108
12	8	477817.3562	465267.0682	346148.454	207292.5113	1740
13	9	636489.9525	623939.6645	504821.0503	365965.1076	3327
14	10	657168.8626	644618.5746	525499.9604	386644.0177	353
15	11	611631.9518	599081.6638	479963.0496	341107.1069	3079
16	(blank)					
17	Grand Total	4046766.157	3933813.565	3087461.688	2477743.302	2251