



SQUAD: A Tool for Spatial Quality and Anomalies Diagnosis

Documentation and Tutorial
ArcGIS Version

Revised May 2018

MS-17-120



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The tool was written by John Spencer and Becky Wilkes of the USAID- and PEPFAR-funded MEASURE Evaluation, University of North Carolina at Chapel Hill.

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ABBREVIATIONS

CSV	comma-separated values
GIS	geographic information system
GPS	global positioning system
SQUAD	spatial quality and anomalies diagnosis
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

BACKGROUND

The Need for the Tool and the Logic Behind It

Data are essential to a well-functioning health system. An explosion in the quantity of data has prompted an increasing emphasis on how this information can advance global health. Within this burgeoning “data tsunami,” as some have called it, are rich streams of data on the populations at risk and in need of treatment for HIV and other illnesses, the services being provided, and the context in which these both exist. Many of these data streams have a geographic component. We know more about “where things are” than ever before. Knowing where a health clinic or dispensary is located can be useful in making decisions about how best to provide public health services for a certain size or type of population, or to handle referrals from other nearby facilities.

These kinds of geographic data coordinates are easier than ever to collect, by using a smartphone, tablet, or Global Positioning System (GPS) receiver. When the coordinates are stored in a table or spreadsheet, they can be shown on a map.

One way to ensure that the coordinates are accurate is to plot the locations in a geographic information system (GIS) and then carefully examine the attribute data associated with the points. The data table can be

The Value of This Manual

Large spatial data sets can be used to locate disease hot spots or health facilities where services are needed. However, these data can be difficult to check for quality without a time-consuming examination by a trained GIS technician. This new tool—called the Spatial Quality and Anomalies Diagnosis (SQUAD) Tool (<https://www.measureevaluation.org/resources/tools/geographic-information-systems/squad-tool>)—can help a GIS novice identify potential errors in a location-based data set (such as a master facility list) in a short period. This document proposes data correction strategies, based on the tool's output.

quite large, involving many hundreds or thousands of points. Reviewing each point location for accuracy and correctness in such a large database can be time-consuming, tedious, and challenging because of the complex relationship between the spatial characteristics and the associated attributes of the data points. That's why ensuring geographic data quality ordinarily requires the skills of an experienced GIS technician.

The Spatial Quality and Anomalies Diagnosis (SQUAD) tool provides a

framework for assessing the overall quality of a spatial database. It can be run by someone with minimal experience using a GIS, and results in a consistent, clear assessment of potential problems with a given spatial database. Once potential anomalies have been identified, the specific records in question can then be examined in detail and the errors can be corrected. By running this tool, you can get a clear picture of the extent and type of the problems that might be associated with a given geographic data set. This will help you prioritize solutions for improving the data.

The tool checks for six anomalies that are based on common errors in point-location data sets. This information can be used to prioritize the type and extent of investigation needed for records that may have problems.

The anomalies that can be checked are:

1. Missing coordinates

2. Truncated coordinates (lack of adequate precision)
3. Duplicate coordinates for distinct records
4. Duplicate key attributes (two identical names, but plotting in different locations)
5. Coordinate not located exactly where it would be expected (but falling within two kilometers of a border)
6. Coordinate not located anywhere near where expected

The presence of some anomalies *may* not mean there are errors (for instance, there could indeed be two different sites with the exact same name). Anomalies such as these, though, will merit examination to make sure that they are not errors.

Although additional data quality assessment will likely be required, this framework is a starting point for examining a large data set in an efficient manner. If these errors are identified early, the data set can be corrected and made stronger, more useful, and more trustworthy.

Now, let's walk through a practice session with the tool.

Scenario

Your health ministry has done extensive data collection to locate every health facility in the country. The data, in the form of facility names, districts, and GPS (global positioning system) coordinates, must now be checked for quality assurance.

You need a quick but systematic way to find out whether each facility is located in its expected location on the country district map, and if not, why not. By getting a look at the scope of potential problems in this new data set, you can plan how to fix them. A good-quality data set will boost confidence and ensure maximum utility in the future.

What You Will Need

The SQUAD tool is stored as a toolbox and associated script that runs in ArcGIS on the data in question. It requires ArcGIS version 10.3 or later, with an advanced license. The facility point file (containing the facility's X and Y coordinates and attributes) and the associated administrative unit file (with names and outlines of districts or regions) must both be stored either as *shapefiles* or as *feature classes in a geodatabase*. These types of GIS files all store both geometry information (points, lines, and area locations) and attribute information (names and other characteristics of things at each location). See **Appendix A** for what to do if your X and Y coordinates are stored in a spreadsheet and need to be plotted to a point file.

These files can be stored either in WGS84 (World Geodetic Survey, 1984) unprojected format or in an appropriate Universal Transverse Mercator (UTM) projection (so that measurements can be made in meters). More information about coordinates and projections is available in **Appendix B**.

Here are the requirements for each feature class (or shapefile) attribute data table:

1. Facility (point) feature class should include the following:
 - a. Unique ID: a unique identifier for a facility
 - b. Separate fields for the X (longitude) and Y (latitude) coordinates of the site (these should be in decimal degrees)

- c. Site name: Name of the site or facility
 - d. Admin: Name of the administrative unit where the site is located
- 2. District feature class
 - a. A field with a name for the administrative unit (such as a district name)

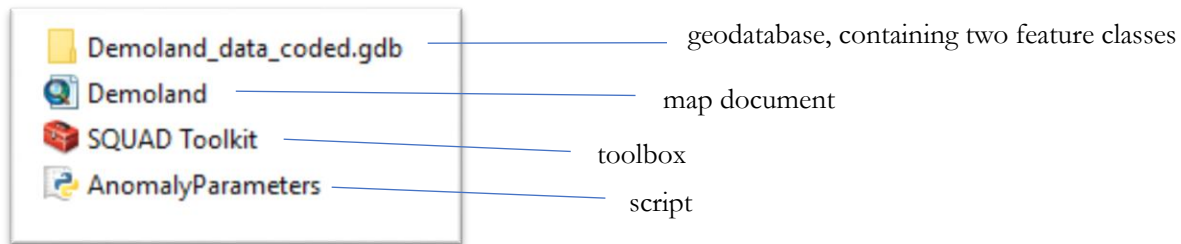
For our scenario, we use the sample data provided with the tool on the MEASURE Evaluation website. The database contains one feature class representing all the facility point locations and another feature class that contains the boundaries and names for all associated districts in a sample country—available at:

<https://www.measureevaluation.org/resources/tools/geographic-information-systems/squad-tool/squad-tool-zip-file>.

SQUAD TOOL TUTORIAL

Exploring the Map Document

Here are the files that come with this demonstration, as viewed in Windows:

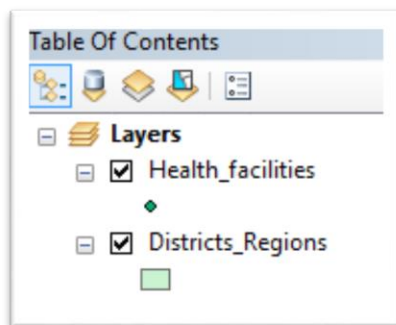


You will not be able to view the geodatabase from within Windows. However, we have set up a **map document file** in ArcMap to get you started; the map document is preloaded with sample versions of each of the feature classes as a map layer.

STEP 1

Double-click on the *Demoland.mxd* document to open ArcMap and view the data.


With each of the feature classes loaded into the map document, you will be able to view (and symbolize) them in the Table of Contents panel:

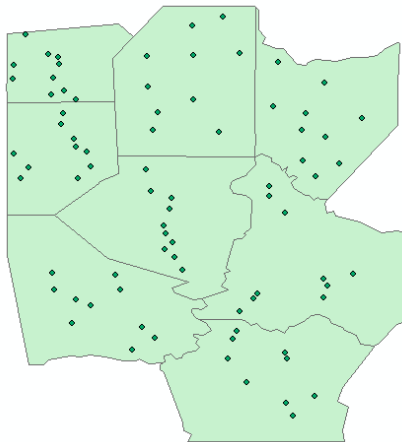


And see their geometry in the main map window:

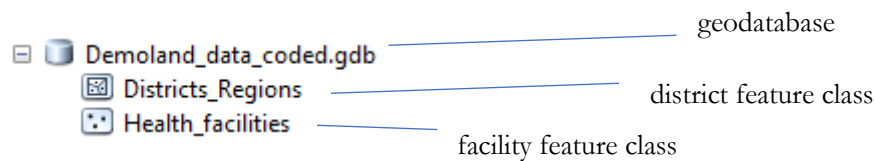
NOTE: You are viewing the contents of an imaginary data set comprising 80 “facilities” and 8 “districts.” A map document is a visual representation of the original data, which in this case is still housed in the “Demoland data_coded” geodatabase.

STEP 2

You can use Catalog view from within ArcMap by **clicking** on the Catalog Panel icon  in the toolbar. If you navigate to the location of the geodatabase from within this panel, you will be able to open it



by using the +/- **toggle** to the left of its name, and see the two feature classes whose data are being displayed in this map document:

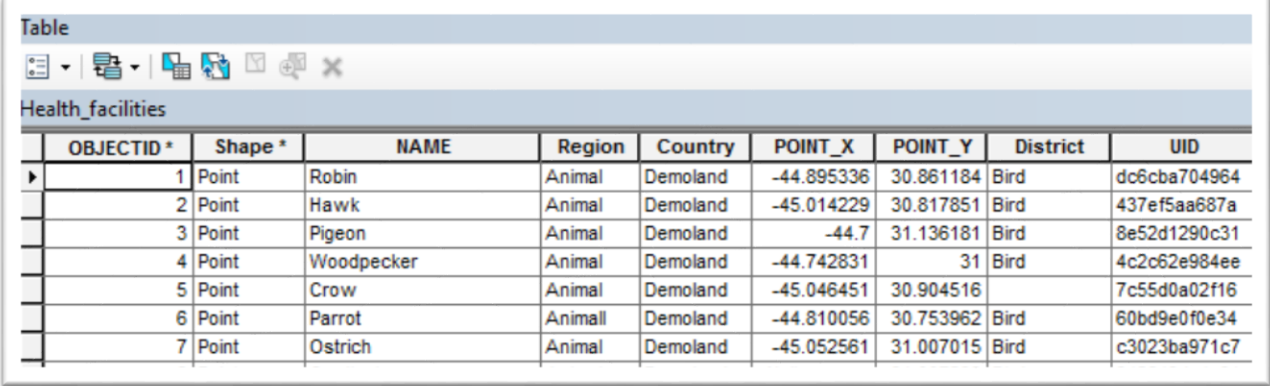


NOTE: The main geodatabase is symbolized by a canister (because it can hold a number of feature classes). The *District_Regions* file is symbolized by polygons, because it represents areas. The *Health_facilities* file is symbolized by points, because it represents discrete locations.

Familiarizing Yourself with the Data

STEP 1

Right-click on the *Health_facilities* layer in the Table of Contents and choose *Open Attribute Table*. Observe the fields that house the attribute data associated with these data points and read about each of them below.

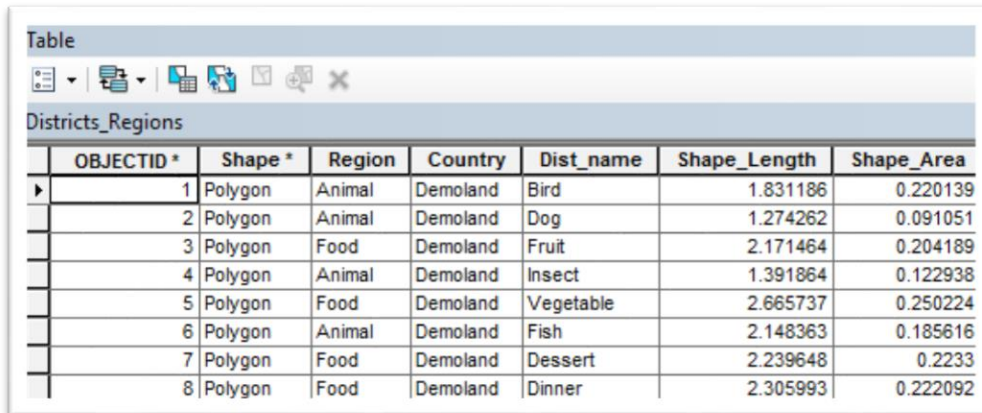


	OBJECTID *	Shape *	NAME	Region	Country	POINT_X	POINT_Y	District	UID
▶	1	Point	Robin	Animal	Demoland	-44.895336	30.861184	Bird	dc6cba704964
	2	Point	Hawk	Animal	Demoland	-45.014229	30.817851	Bird	437ef5aa687a
	3	Point	Pigeon	Animal	Demoland	-44.7	31.136181	Bird	8e52d1290c31
	4	Point	Woodpecker	Animal	Demoland	-44.742831	31	Bird	4c2c62e984ee
	5	Point	Crow	Animal	Demoland	-45.046451	30.904516		7c55d0a02f16
	6	Point	Parrot	Animal	Demoland	-44.810056	30.753962	Bird	60bd9e0f0e34
	7	Point	Ostrich	Animal	Demoland	-45.052561	31.007015	Bird	c3023ba971c7

- **OBJECTID** is generated automatically for each record in any ArcGIS table.
- **Shape** is also generated for every ArcGIS table, and indicates that these are points. These fields are mandatory and should basically be ignored for the purposes of this exercise.
- **Name** is the name of each “facility.”
- **Region** and **Country** and **District** all help indicate the position of each facility. We’ll be using the tool to check whether the District records are correct.
- **POINT_X** is the longitude coordinate in decimal degrees. (It is negative, because it is located west of the prime meridian.)
- **POINT_Y** is the latitude coordinate in decimal degrees.
- **UID** is a unique ID field for each facility.

STEP 2

Now, observe the attribute table for the *Districts_Regions* layer (by **right-clicking** on the name in the Table of Contents and **choosing** *Open Attribute Table*.)




	OBJECTID *	Shape *	Region	Country	Dist_name	Shape_Length	Shape_Area
▶	1	Polygon	Animal	Demoland	Bird	1.831186	0.220139
	2	Polygon	Animal	Demoland	Dog	1.274262	0.091051
	3	Polygon	Food	Demoland	Fruit	2.171464	0.204189
	4	Polygon	Animal	Demoland	Insect	1.391864	0.122938
	5	Polygon	Food	Demoland	Vegetable	2.665737	0.250224
	6	Polygon	Animal	Demoland	Fish	2.148363	0.185616
	7	Polygon	Food	Demoland	Dessert	2.239648	0.2233
	8	Polygon	Food	Demoland	Dinner	2.305993	0.222092

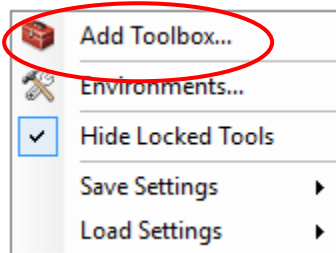
The important field to note here is

- **Dist_name.** There is one unique name for each district on the map.

Running the Tool

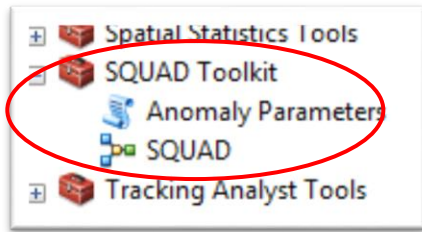
STEP 1

Now, from inside your map document file, **load the SQUAD Toolkit**. First, open the *ArcToolbox Panel*, by **clicking** on its icon  and then **right-clicking** in the Toolbox panel and choosing *Add Toolbox...*



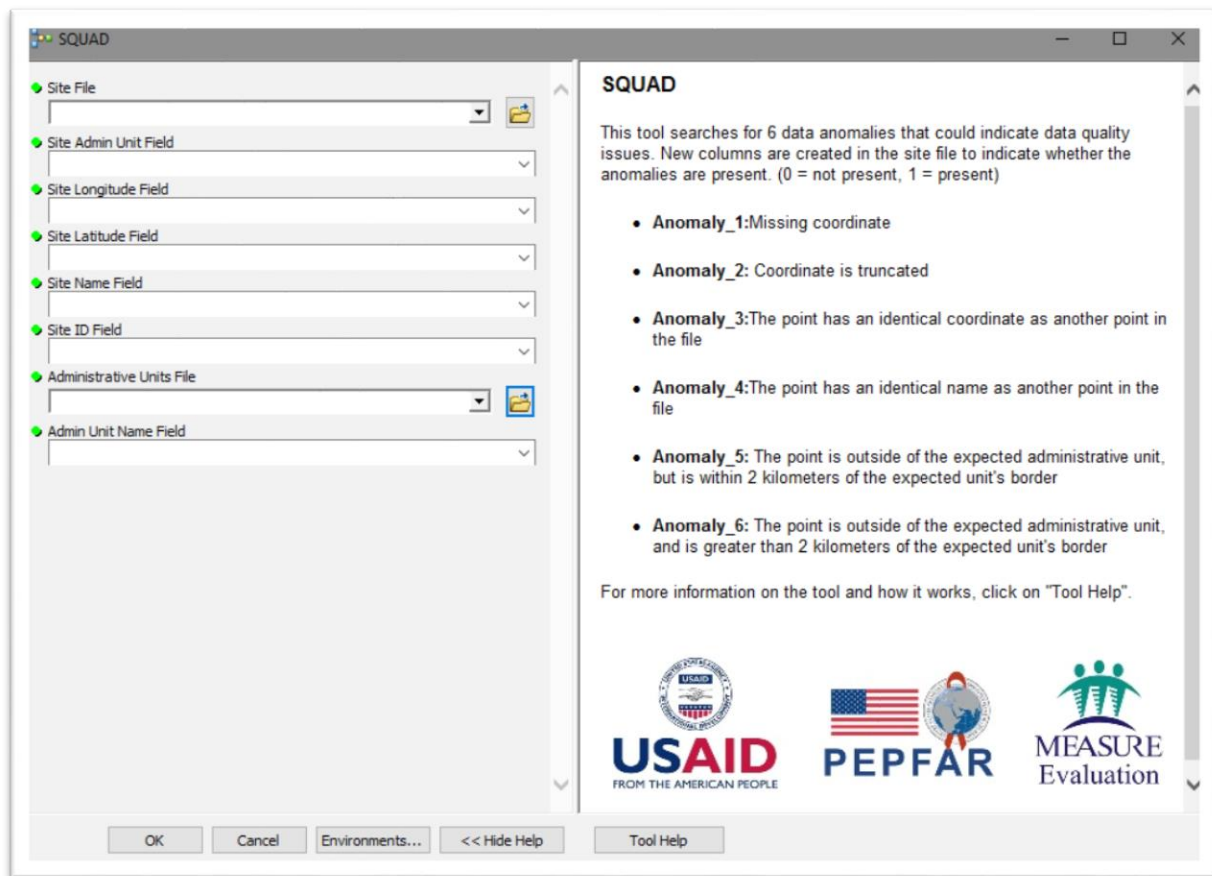
then **browsing** to the *SQUAD Toolkit* file and **selecting** it.

Here is the resulting ArcToolbox Panel view, showing the SQUAD tool (you may need to toggle the +/- button to the left of the toolbox to reveal its contents):




STEP 2

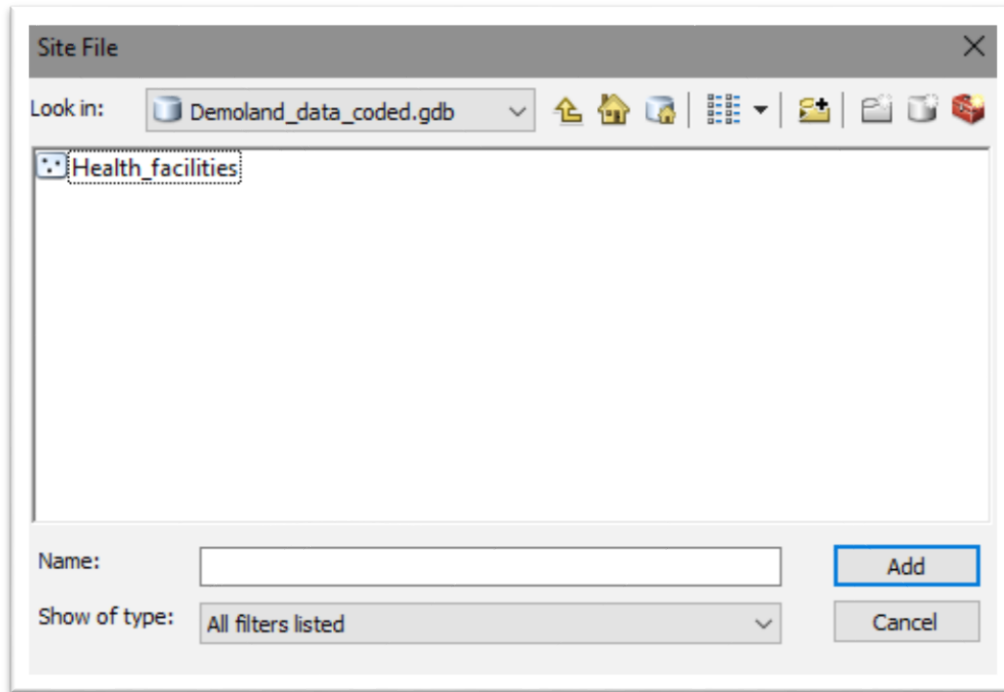
To **run** the tool, **double-click** on its name in the Toolbox Panel (*SQUAD*). You should see the following large dialog box:



The left panel contains a series of drop-down choices, and the right panel contains a brief description of the tool. (To see even more information about the tool, **click** on *Tool Help* near the bottom of this panel.)

STEP 3

To get started, **click** on the little *browse* button  beside the box labeled *Site File*. The instructions in the right panel will update (please read through these), and a browser dialog will open. **Navigate** to the location of the *Demoland* geodatabase and then to the *Health_facilities* feature class, then **choose** *Add*.



STEP 4

Next, **click** on the *Site Admin Unit Field* drop-down **toggle**:

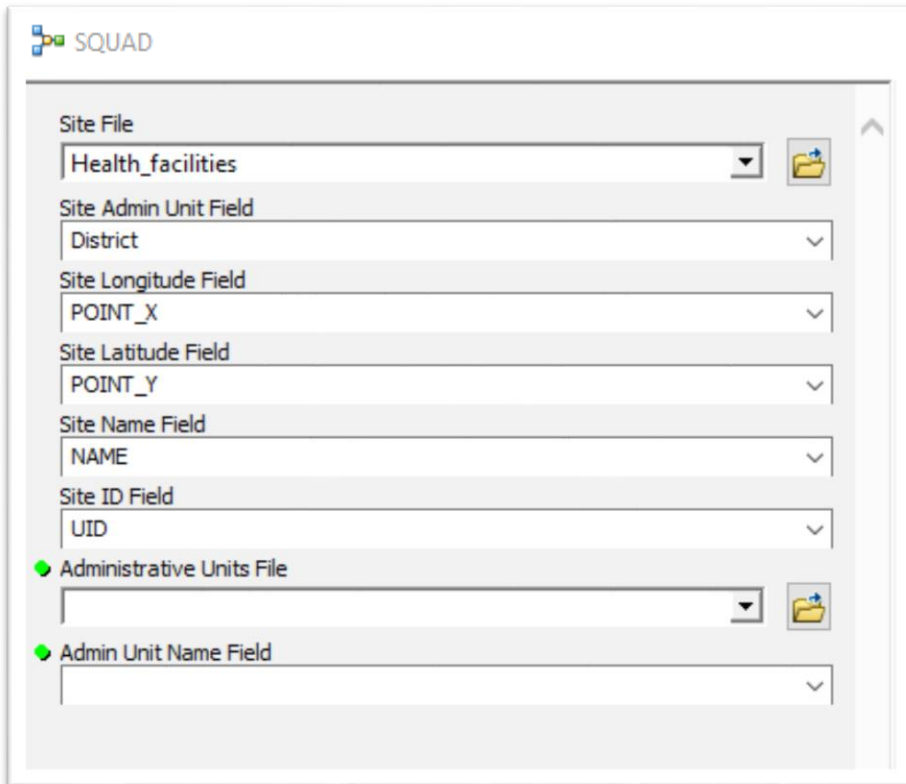


You should recognize the list of all the fields in the feature class table for *Health_facilities*. Which one should you choose? (In this case, the name of the field you want to compare to the *District* file is simply “**District.**”)

STEP 5

For *Site Longitude Field*, choose **POINT_X**, and for *Site Latitude Field*, choose **POINT_Y**. And for *Site Name Field*, remember, that field in our demo table is simply called **NAME**. The Site ID is called **UID**.

Here's what our dialog box looks like so far:



The screenshot shows the SQUAD dialog box with the following configurations:

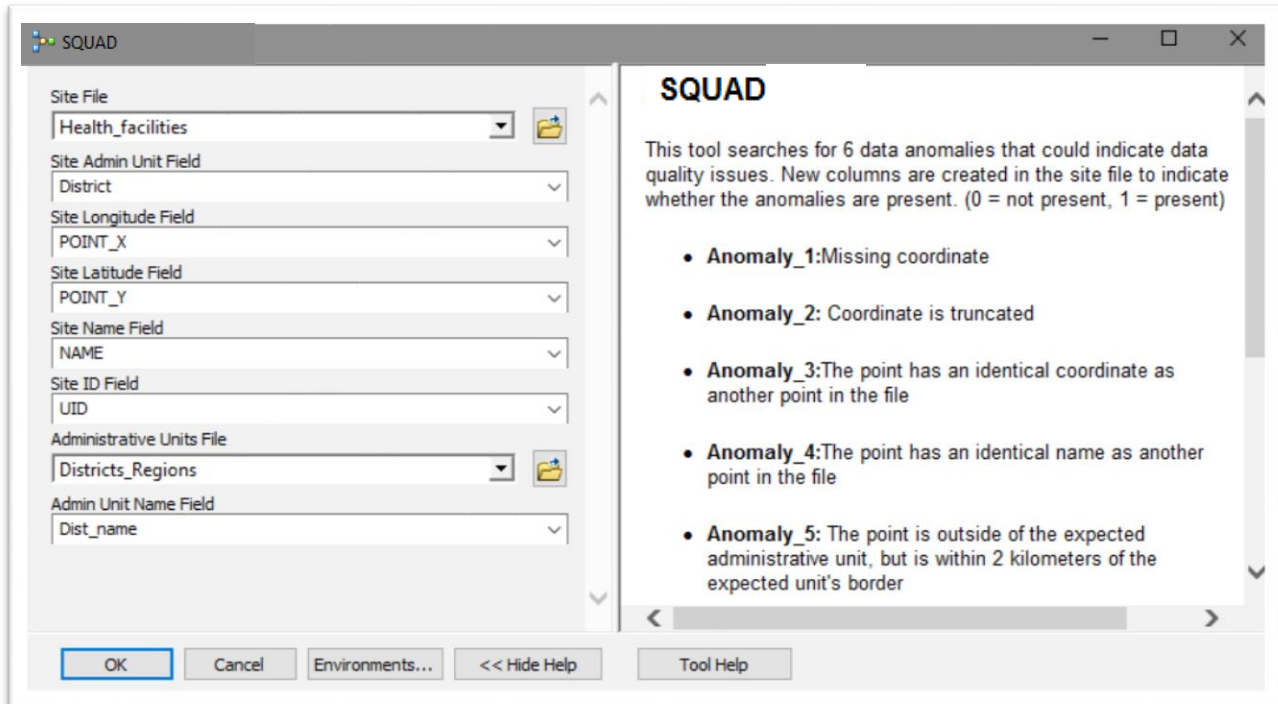
- Site File:** Health_facilities
- Site Admin Unit Field:** District
- Site Longitude Field:** POINT_X
- Site Latitude Field:** POINT_Y
- Site Name Field:** NAME
- Site ID Field:** UID
- Administrative Units File:** (empty)
- Admin Unit Name Field:** (empty)

STEP 6

Next, we need to **browse** to the feature class file, which contains the *administrative units* we are checking. (Remember, this feature class is called *Districts_Regions*.)

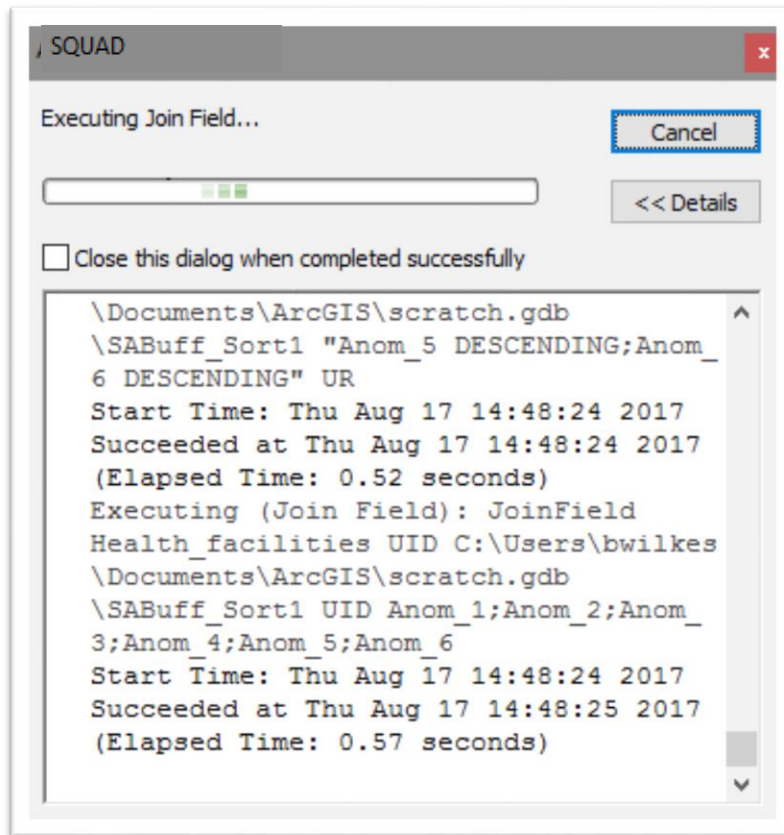
Finally, we need to **choose** the field in this feature class that contains the name of the districts, which in this case is *Dist_Name*.

When all fields have been completed, there will be no more green bullets left, and the dialog box should look like this:



STEP 7

Review everything one more time to make sure all the correct files and fields have been chosen, then **click OK**. The tool will start running and a status box will appear, which will be updated as each command in the tool is executed.



When the tool is done running, this box will say "Completed." You may then click *Close*.

Your anomaly fields will have been added to the *Health_facilities* feature class.

Observing the Results

STEP 1

Open the *Health_facilities* attribute table, if it isn't open already. (Hint: **Right-click** on its name in the Layers Panel to find the correct command.) You should see 6 new fields that have been added by the tool.

STEP 2

Right-click on the field called **Anomaly_1** and choose *Sort Descending*. You should see that the table has now been sorted based on that field, so that all the 1's are at the top of the table.

NAME	Region	Country	POINT_X	POINT_Y	District	UID	Anomaly_1
Cardinal	Animal	Demoland	<Null>	31.007293	Bird	942843dc4a91	1
Strawberry	Food	Demoland	<Null>	30.49591	Fruit	ff186dbb53d4	1
Pudding	Food	Demoland	-44.717824	<Null>	Dessert	26be832159a7	1
Ravioli	Food	Demoland	<Null>	<Null>	Dinner	d893a9d8c823	1
Robin	Animal	Demoland	-44.895336	30.861184	Bird	dc6cba704964	0

Look at each of these records. For the facility named “Cardinal,” the X field is empty. And for “Ravioli,” both the X and Y fields are empty. (<Null> is a database term for “empty,” or “no value”). “Anomaly 1” is the code for missing coordinates. These will need to be checked.

STEP 3

Now **right-click** on each of the other anomalies in turn, choosing *Sort Descending* to bring the ones coded with a 1 to the top. **Can you determine** what the problems might be for these records? Remember, Anomaly 2 indicates truncated coordinates, Anomaly 3 indicates duplicate locations, and Anomaly 4 indicates duplicate facility names.

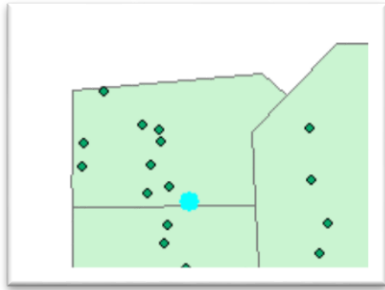
STEP 4

Anomalies 5 and 6 both apply to locations (according to given coordinates) not falling into their expected districts.

To **examine** Anomaly 5 on the map, **right-click** on the field name and choose *Sort Descending*. Then **click on the small box** to the very left of that record.

Health_facilities				
	OBJECTID *	Shape *	NAME	Region
	11	Point	Poodle	Animal


This will “select,” or **highlight**, that particular point. In fact, you will see the selection highlight in both the attribute table and the map window at the same time.

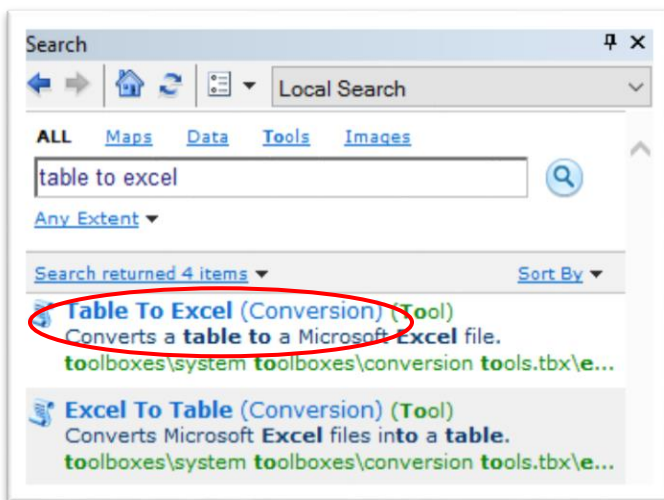


Do this for the points that have 1's marked for Anomaly 5 and for Anomaly 6. **What is the difference?** (Hint: The Anomaly 5 point is very close to a border.) What do you think is wrong with the Anomaly 6 points? (Hint: To check if a point is falling in the correct district, try **labeling** the districts with their names. To do this, **right-click** on *Districts_Regions* in the Layers Panel, then choose *Label Features*. Then highlight the “Pear” facility in the *Health_facilities* attribute table. In which district should it supposedly be?)

STEP 5 (optional)

Export the table with anomalies to Excel.

Click on the *search* button  in the toolbar. In the search box in the panel that pops up, **type** “table to excel” to find the *Table to Excel* tool.



Double-click on the tool to open the dialog box. **Choose** the *Health_facilities* layer as the input table; **choose** an output location; then **click** “OK.”

DATA CORRECTION PROCESS

When beginning the data correction process, here are some suggestions for dealing with each of the different types of anomalies.

Anomaly 1. Missing coordinates

- Review the data collection sheet, if available, and see if records were omitted.
- Obtain the actual coordinates of a facility, using a handheld GPS receiver (or mobile phone).

For more on GPS data collection, see the following resources:

1. Mini-tutorials (5- to 10-minute videos) published by MEASURE Evaluation that can help beginners collect GPS coordinates, download the data to a computer, and carry out other basic GIS tasks:
<http://www.measureevaluation.org/resources/training/online-courses-and-resources/non-certificate-courses-and-mini-tutorials/gis-step-by-step-tutorials/>
 2. Information on collecting data using a GPS receiver:
http://www.measureevaluation.org/resources/training/capacity-building-resources/geographic-information-systems-mapping-and-analysis-of-spatial-data/tools-tips/FS1383_GPScoordinates_Dec2013.pdf/view
- Obtain the coordinates by using a visual examination in Google Maps or Google Earth. (A cursor placed over a known nearby road intersection, for instance, will display the coordinates in the lower right-hand corner of the screen.)

For more information on using Google Maps to search locations, see the following:

<http://support.google.com/maps/answer/3092445>

Anomaly 2. Truncated coordinates (lack of adequate precision)

- Review the data collection sheet, if available, and see if records were incorrectly transferred or if digits were left off or rounded.
- Obtain the actual coordinates of a facility using a handheld GPS receiver or mobile phone (*see links above*).
- Obtain the coordinates by using a visual examination in Google Maps or Google Earth. (For example, a cursor placed over a known nearby road intersection will display the coordinates in the lower right-hand corner of the screen; *see the link above*).

Anomaly 3. Duplicate coordinates for distinct records.

- Investigate to determine whether the anomaly is really an error. (It could be correct, such as in the case of a dispensary located at the same address as a hospital.)

Anomaly 4. Duplicate key attributes

- Investigate to determine whether the anomaly is really an error. (It could be correct, such as in the case of two clinics in different parts of the country having the same name).

Anomaly 5. Coordinate not located where expected, but falling within 2 kilometers of a border

- Review the data collection sheet, if available, to confirm coordinates.
- Obtain an administrative boundary file from a different source (a point falling very close to a boundary could indicate that the boundary itself is wrong or inaccurate).

A good source is the GADM database (Global Administrative Areas): <http://www.gadm.org/>

- Validate coordinates using imagery such as ArcGIS or Google Earth.

For information about adding imagery from within ArcGIS:

<http://desktop.arcgis.com/en/arcmap/10.3/map/web-maps-and-services/about-adding-an-image-service-layer.htm>

For information about Google Earth:

<http://www.google.com/earth/>

Anomaly 6. Coordinate not located anywhere near where expected

- Review the data collection sheet, if available, to confirm coordinates.
- Check the spelling of administrative units in the administrative boundary file.
- Check to confirm that the point file has correct administrative area designations.
- Validate the coordinates using imagery such as ArcGIS or Google Earth, or re-collect the data using a GPS receiver or mobile device.

CONCLUSION

The SQUAD tool is useful for assessing the quality of a spatial database and does not require extensive GIS experience to run. The scenario we described provides a hands-on exercise in running the tool and the types of potential errors that may be revealed. The anomalies provide a quick view of the scope of the problems in a given file. Low numbers of anomalies indicate that the quality of the spatial data is good overall.



APPENDIX A

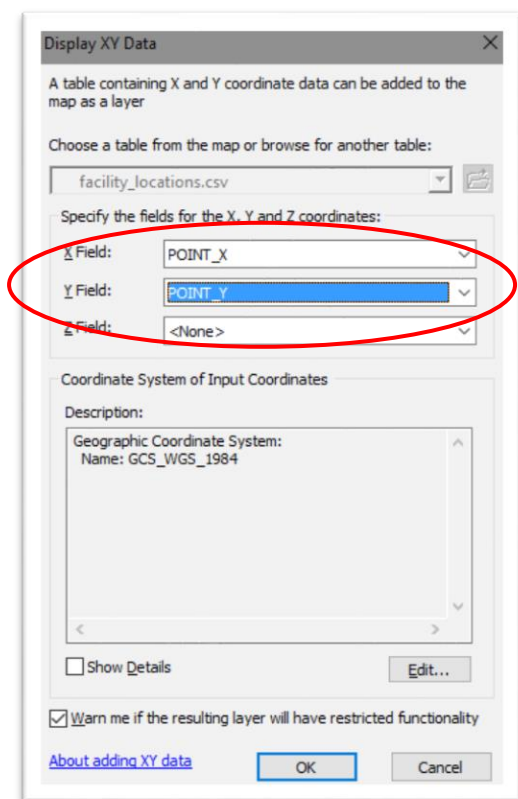
Converting a Spreadsheet Containing (X, Y) Coordinates into a Point File (Shapefile or Feature Class) in ArcGIS

The tool requires all inputs to be in the form either of shapefiles or feature classes in a geodatabase. If you are starting from a spreadsheet that lists coordinate locations, you can plot these using ArcGIS and then export the result to a point file that contains the geometry and attributes for all the locations. For a detailed explanation, please refer to the following ESRI Technical Support article:

<http://support.esri.com/en/technical-article/000012745>

Here are the basic steps:

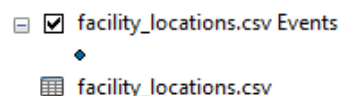
1. **Open** your spreadsheet in a program such as Excel and **save** it as a CSV (comma-separated values) file. (This assumes your spreadsheet contains separate columns for the X and Y coordinate values, and that the values are in decimal degrees format, stored with a precision of at least five decimal places.)
2. **Open** ArcGIS and **click** the *Add Data* button.  **Browse** to the CSV file and **click** *Add*. You should see the file appear in the Layers panel.  **facility_locations.csv**
3. **Right-click** on the name of the CSV file in the Layers panel and **choose** *Display XY Data* in the drop-down menu.
4. A dialog box will appear:



Select the X field (the field containing the longitude values) and the Y field (the field containing the latitude values) from the CSV file. (If your coordinates are not in this format, you may need to see more about coordinate systems and projections in Appendix B. Most frequently, GPS data is collected in the WGS 1984 datum, so you will likely not need to change the default coordinate system here.)

Click OK.

5. Your points should plot to the main map screen, and a new Event Layer will appear in the Layers panel.



6. The “Events” file is temporary, so you will need to **save** it to a shapefile (or geodatabase feature class). **Right-click** it and say Data>Export Data. . . **Choose** a location, format, and name; then **choose** OK. Now you have a shapefile containing your X, Y locations. This file can be used with the SQUAD tool.

APPENDIX B

Coordinate Systems and Projections: FAQ

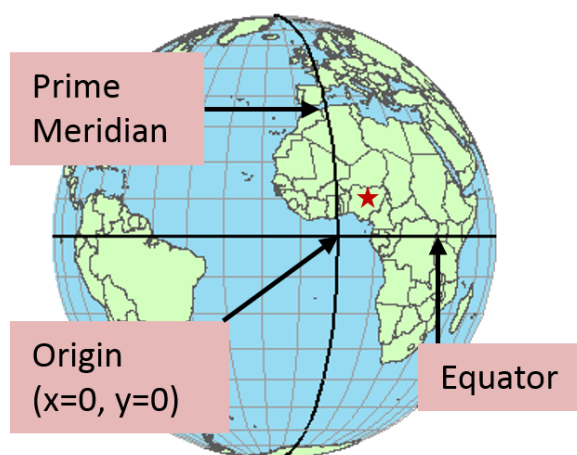
What is a projection?

There are two main ways to refer to coordinate locations on the Earth.

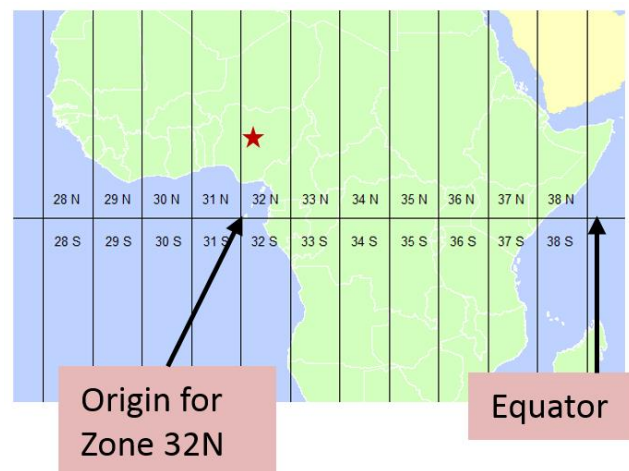
“Unprojected” coordinates are those that refer to a point on the globe (sphere). For this system, coordinates are measured in **degrees** (0 to 90 degrees North or South of the equator is the latitude; 0 to 180 degrees East or West of the prime meridian is longitude). These can be further specified as degrees, minutes, and seconds (D-M-S), or as decimal degrees (there are many conversion programs online to go from DMS to DD).

“Projected coordinates” are those coordinates projected onto a flat surface, such as a map. These are also called Cartesian coordinates. These are the X, Y coordinates used in algebra and on graphs. In a UTM projection system, the Earth has been projected onto a flat surface and portioned into zones. Each zone has an origin, or 0,0 starting point, in its lower left corner. Each set of coordinates is measured in **meters** from the zone’s origin.

For comparison, here are illustrations of unprojected coordinates for Abuja, Nigeria (on the left) and projected (UTM) coordinates for the same location (on the right).



★ **Abuja, Nigeria:**
9.05129° N, 7.48482° E
or 9°03'07" N, 7°29'08" E



★ **Abuja, Nigeria:**
333500 E, 1001500 N, zone 32E

A more detailed and further illustrated explanation of coordinate systems and Earth geometry can be found here:

<http://kartoweb.itc.nl/geometrics/Coordinate%20systems/coordsys.html>

How do I determine what UTM zone to use?

An explanation and map of zones can be found here:

http://www.maptools.com/tutorials/grid_zone_details

or here: <http://geokov.com/education/utm.aspx>

To determine a location's UTM zone, you can generally just type in the name of the location and "UTM zone" in Google to get an easy answer, then double-check your findings with one of the above charts.

How do I determine what projection I am working with in ArcGIS?

To see if your data source has a coordinate system defined, right-click the layer in the ArcMap table of contents, and click **Properties** to open the **Layer Properties** dialog box. Click the **Source** tab, then look in the **Data Source** box. You can also use the **Catalog** window to see if your data has a defined coordinate system.

ArcGIS comes with tools for defining and changing coordinate systems. For more information, see this link:

<http://desktop.arcgis.com/en/arcmap/10.3/map/working-with-arcmap/specifying-a-coordinate-system.htm>

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