GIS

Succinctly

by Peter Shaw

Syncfusion | Technology Resource Portal

Important licensing information. Please read.

This book is available for free download from www.syncfusion.com on completion of a registration form.

If you obtained this book from any other source, please register and download a free copy from www.syncfusion.com.

This book is licensed for reading only if obtained from www.syncfusion.com.

This book is licensed strictly for personal, educational use.

Redistribution in any form is prohibited.

The authors and copyright holders provide absolutely no warranty for any information provided.

The authors and copyright holders shall not be liable for any claim, damages, or any other liability arising from, out of, or in connection with the information in this book.

Please do not use this book if the listed terms are unacceptable.

Use shall constitute acceptance of the terms listed.

Edited by

This publication was edited by Jay Natarajan, senior product manager, Syncfusion, Inc.

Table of Contents

The Story behind the *Succinctly* Series of Books

Daniel Jebaraj, Vice President
Syncfusion, Inc.

Staying on the cutting edge

As many of you may know, Syncfusion is a provider of software components for the Microsoft platform. This puts us in the exciting but challenging position of always being on the cutting edge.

Whenever platforms or tools are shipping out of Microsoft, which seems to be about every other week these days, we have to educate ourselves, quickly.

Information is plentiful but harder to digest

In reality, this translates into a lot of book orders, blog searches, and Twitter scans.

While more information is becoming available on the Internet and more and more books are being published, even on topics that are relatively new, one aspect that continues to inhibit us is the inability to find concise technology overview books.

We are usually faced with two options: read several 500+ page books or scour the web for relevant blog posts and other articles. Just as everyone else who has a job to do and customers to serve, we find this quite frustrating.

The *Succinctly* series

This frustration translated into a deep desire to produce a series of concise technical books that would be targeted at developers working on the Microsoft platform.

We firmly believe, given the background knowledge such developers have, that most topics can be translated into books that are between 50 and 100 pages.

This is exactly what we resolved to accomplish with the *Succinctly* series. Isn't everything wonderful born out of a deep desire to change things for the better?

The best authors, the best content

Each author was carefully chosen from a pool of talented experts who shared our vision. The book you now hold in your hands, and the others available in this series, are a result of the authors' tireless work. You will find original content that is guaranteed to get you up and running in about the time it takes to drink a few cups of coffee.

Free forever

Syncfusion will be working to produce books on several topics. The books will always be free. Any updates we publish will also be free.

Free? What is the catch?

There is no catch here. Syncfusion has a vested interest in this effort.

As a component vendor, our unique claim has always been that we offer deeper and broader frameworks than anyone else on the market. Developer education greatly helps us market and sell against competing vendors who promise to “enable AJAX support with one click,” or “turn the moon to cheese!”

Let us know what you think

If you have any topics of interest, thoughts, or feedback, please feel free to send them to us at succinctly-series@syncfusion.com.

We sincerely hope you enjoy reading this book and that it helps you better understand the topic of study. Thank you for reading.

Please follow us on Twitter and “Like” us on Facebook to help us spread the word about the *Succinctly* series!

About the Author

As an early adopter of IT in the late 1970s and early 1980s, I started out with a humble little 1-KB Sinclair ZX81 home computer.

Within a very short amount of time, this small, 1-KB machine led to a 16-KB Tandy TRS-80, followed by an Acorn Electron, and eventually, after going through many different machines, a 4-MB ARM-powered Acorn A5000.

After leaving school and getting involved with DOS-based PCs, I went on to train in many different disciplines in the computer networking and communications industry.

After returning to university in the mid-1990s and receiving a BSc in computing for industry, I now run my own consulting business in the northeast of England called Digital Solutions Computer Software Ltd., where I advise clients on both hardware and software in many IT disciplines, covering a wide range of domain-specific knowledge from mobile communications and networks, to geographic information systems, to banking and finance.

With more than 30 years of experience in the IT industry across varied platforms and operating systems, I have a lot of knowledge to share.

You can often find me hanging around the LIDNUG .NET users group on LinkedIn that I help run, and you can easily find me in the usual places such as Stack Overflow (and its GIS-specific board), and on Twitter as @shawty_ds.

I hope you enjoy the book, and learn something from it.

Please remember to thank Syncfusion (@Syncfusion on Twitter) for making this book and others in the series possible, allowing people like me to share our knowledge with the .NET community at large. The *Succinctly* series is a brilliant idea for busy programmers.

Introduction

Geographic information systems (GIS) are all around us in this day and age, but most people, even developers, are not aware of the internals. Many of us use GIS through web-based systems such as Google Maps or Bing Maps; as GPS data that drives maps and address searches; and even when tracking where your latest parcel from Amazon is.

The world of GIS uses a complex mix of cartography, statistical analysis, and database technology to power the internals that drive all the popular external applications we all use and enjoy. In this guide I'll be showing you the internals of this world and also how it applies to .NET developers who may be interested in using some GIS features in their latest application.

Chapter 1 So, what exactly is a GIS?

To most people, what they see as a GIS is in fact just the front-end output layer, such as the maps produced in Google Maps, or the screen on a TomTom navigation device. The reality of it all extends far beyond that; the output layer is very often the end result of many interconnecting programs along with massive amounts of data.

A typical GIS will include desktop applications used to visualize, edit, and manage the data, several different types of backend databases to store the data, and in many cases a huge amount of custom written software tools. In fact, GIS is one of the top industries where a programmer can expect to write a very large amount of custom tooling not available from other companies.

We'll explore some of the applications in detail soon, but for now we'll continue with the 100-foot view. A typical GIS processing setup will look something like the following:

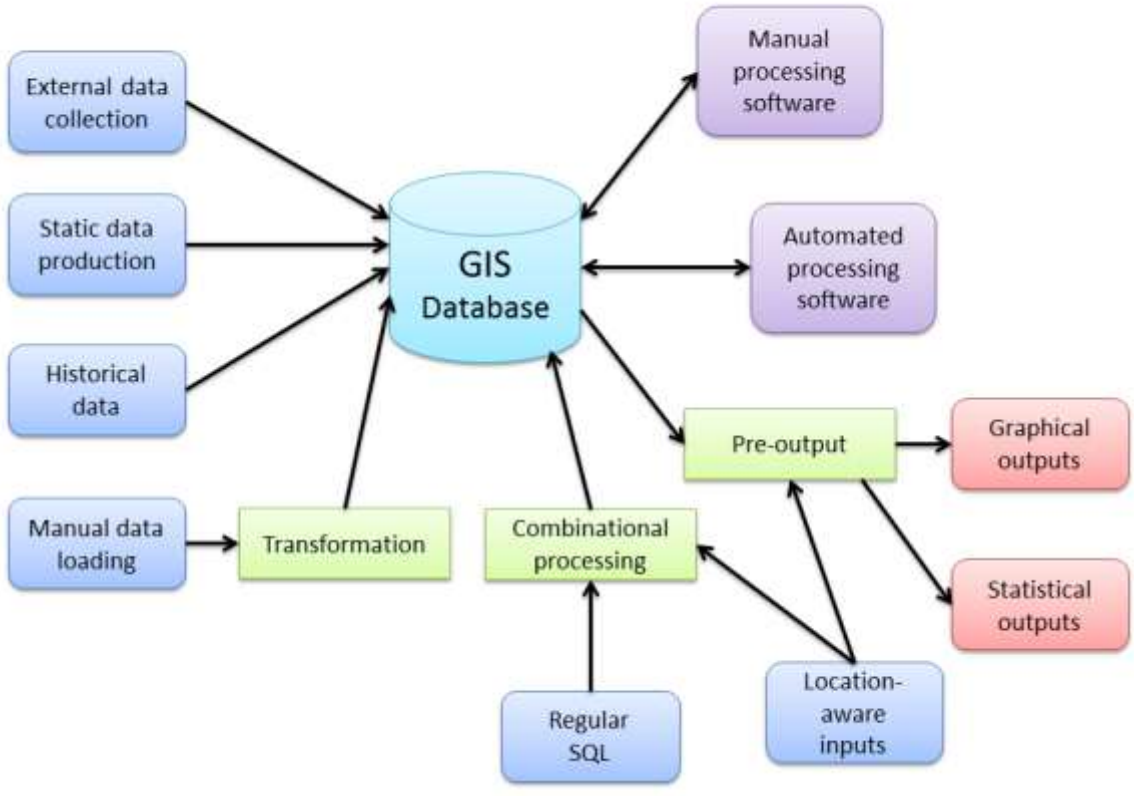


Figure 1: Typical GIS processing setup

As you can see in the diagram, the central part is very often the database itself with a huge number of inputs and processing steps. Finally, the output layers (shown in red) are what people usually associate with being a GIS.

Based on this, we can see that the database is the center of the universe when it comes to GIS.

A Breakdown of the Components

Looking at the diagram in Figure 1, we can see that there are a number of parts that have specific meanings. We have our inputs (blue), outputs (red), in-place processing (green), and end processing (purple). At this point you might be asking yourself, "How is this different from any other data-centric system I deal with?" and you'd be right to do so. The main difference here is that in a typical GIS, you have to design everything in each component from the very beginning. With a regular data-centric system, many of the components are often optional or are combined into multifunctional components.

For a typical GIS, none of what you see in Figure 1 is optional, except for possibly your inputs. Even then, the components you'll most likely see omitted are manual and historical data.

So what do these separate entities entail, and why are they often not optional?

External Data Collection

As the name suggests, this is the process of gathering external data specific to the system being designed. Typically this will come from custom devices running custom software (often embedded or small scale) designed to create input data in a very specific form for the system it is being used in. The lack of any in-place processing generally means the data produced is in a format that is already acceptable in the setup.

This component is typically satisfied by many diverse pieces of technology, and in most cases requires some training to use correctly. You'll often see things like digital surveying equipment or specialized GPS devices fitted to vehicles, which in many cases will often feed data back in real time using some kind of radio connection.

Static Data Production

Like external data, this process normally gathers data in a specific format for the system it is being used in. Unlike external data however, you will generally find that static data is produced in-house by scanning existing paper maps or digitizing features from existing building plans, for instance.

Like external inputs, static data is often produced using custom software and processes specific to the business.

Historical Data

Because of the size and amount of data produced in a typical GIS setup, there is often a need to back up data into a separate archival system while still maintaining the ability to work with it if needed. Often, data of this nature is created by planning authorities showing things like land use over time or recording where specific points of interest are. This is treated as a separate input because the data is usually read only, and similarly to external and static data, was at one time produced specifically for the system.

Manual Data Loading

While the name of this type of input may suggest the same as external data, the actual data obtained in this step is usually very different. Data coming into the system via this input will often be in the form of pre-provided data from a GIS data provider. In the United Kingdom, this will often mean data provided by companies like Ordnance Survey. In the United States, this might mean data provided by institutions such as the U.S. Geological Survey or TIGER data from the U.S. Census Bureau.

At this step, wherever data is obtained from, it's almost guaranteed that it will need to be transformed into a format that is useable in the GIS it's destined for. More often than not, it will need to go through some kind of in-place process before it's useable in any way.

Regular SQL Queries

Since most GIS have a large database at the center of them, SQL still plays an important role and probably always will. However, in GIS terms, these queries not only involve the normal SQL that you're used to seeing in a database management system, but also geospatial SQL. We'll cover GIS-specific SQL a little later on; for now, inputs here are usually generated from things like search queries.

As an example, when you type the name of a place or a ZIP code into Google, Bing, or Yahoo Maps, the web application you're looking at will most likely turn your search into a query that uses geospatial SQL to examine data in the core database. This, in turn, will be combined with other processes to produce an output, which in this case will usually be a map displaying the location you searched for. Another example might be an operator in an emergency services control room entering the location of an incident, and combining that with the known locations of nearby emergency vehicles to aid in making a decision as to which vehicle to send to the incident.

Location-Aware Inputs

The last input type is probably the one that is familiar to most people. Location-aware data most often comes from the GPS input on a mobile phone or other GPS-enabled device. It is generally common latitude and longitude information. We'll cover this more when discussing NMEA data.

Graphical Outputs

Now we move to the output layers, the first of which is the graphical one and what most people are familiar with. Output data here is very often in the form of a raster-based map with all operations performed to produce a single output tile in the form of a standard bitmap (such as a .jpeg). However, far more is involved than simple map tiles. Graphical outputs can, and very often are, produced in various vector formats, or as things like AutoCAD drawings for loading into a CAD or modeling package. In fact, even in web environments where people are used to seeing bitmap tiles, it's common for graphical output to take the form of SVG or KML data combined with a custom Google Maps object. Raster tiles are just the tip of the iceberg.

Statistical Outputs

Outputs in this group are the complete opposite of graphical outputs. Data is often the by-product of several GIS–SQL operations based on the input data and processes going on within the system. Just like general database data, from this output you'll get facts and figures that can be used to report statistics to management or marketing teams. The reason we treat this separately, however, is because of the nature of the information.

While you might be tempted to just say, "It's only numbers," in some cases it's numbers that have no meaning unless there is some GIS input involved. As an example, let's say we have a number of geographic areas representing plots of land, and with each of those areas we have a monetary value for that plot.

We can easily say, "Give me the values of each plot in descending order," enabling you to see which is the most expensive piece of land overall. This is where the difference stops, however. Let's say we now know that all land in a district has a 1% tax for every square meter a plot consumes. We know by looking at a graphical output of the map that the visually bigger areas are going to be more expensive, but you can't convey that to a computer.

You can, however, ask using GIS–SQL for a statistical analysis based on a percentage of the land's plot value multiplied by however many square meters are in the defined area boundary.

Manual Processing Software

Anything in the system that requires an operator and some software to make changes falls under the category of manual processing software. Typically, this is both an input and an output because in most cases this involves changes being made to the underlying data manually.

This is usually the area where you'll see large GIS packages such as ESRI, DigitalGlobe, and MapInfo used. We'll cover some of these later. An example of what might be performed at this stage is boundary editing. Let's say that you added some town boundaries as area definitions several years ago, and since they were first added the towns have increased in size. You would then find a GIS expert who, with his or her chosen software and some satellite imagery, would edit your boundary data so that its definition better fits the newly expanded imagery.

Automatic Processing Software

Operations running at this stage are generally not much different than those being run manually. The reason we see a clear separation is because some processes simply cannot be automated and need a human eye to pick out details. Going back to our previous example of the town boundaries, it's not beyond imagination that a process can be defined to analyze an aerial image and determine if boundaries need to be removed.

Most often, however, automatic editing is used to perform tasks such as drift correction or height and contour changes due to earth movement.

Transformation Tasks

As mentioned in the discussion of manual data input, when obtaining data for incorporation into a GIS, the data will rarely be in a format suitable for inclusion in the system.

Making the data usable may involve something as simple as a coordinate transform, or something as complex as combining multiple datasets based on common attributes and more. Transformation processes can and often do seriously affect the overall data quality, and many systems can end up with a lot of deeply rooted problems caused by mistakes when transforming data.

In the U.K., these processes are almost always seen when working with latitude and longitude coordinates, as nearly all the data supplied by U.K. authorities will be in meters from the origin, rather than degrees around the center.

Combinational Processing

Combinational processing is generally in-place processing that is the result of various input operations. It's not too different from using a join in a regular database operation. The result is a combination of processes and input data steps that ultimately work in real time to produce a defined input data set.

Pre-Output

Last but not least is the pre-output step. As the name suggests, this is the final processing required before the output is useable. A pre-output process may include transforming an internal coordinate system to a more global one; for example, U.K. meters back to a global scale, or converting a batch of statistics to a different range of values. Location-aware inputs are often included in this step, typically in a navigation system. For example, a location's graphical representation could be combined with current mapping to produce a visual output for a tracking map.

The Database

So just what makes a GIS database so different from a normal database? Honestly, not much. A GIS database is simply specialized for a particular task.

A better way to illustrate what makes a GIS database unique is to look at the growing world of big data. These days, it's hard not to notice how much noise is being made by NoSQL and document-centric database providers. These new-breed databases fundamentally do the same things as a normal database, but use specialized processes that perform particular operations in better, more efficient ways.

Looking at a GIS database through the lens of a non-GIS connection, the geometric data is nothing more than a custom binary field, or blob, that the software and processes working with the system know how to interpret. In fact, it's possible to take a normal database engine and write your own routines, either in the database or in external code, to perform all of the usual operations you would expect but with GIS data.

In general, when a database is spatially enabled, it will have much more than just the ability to understand the binary data added to it. There will be extensions to the SQL language for performing specialized GIS data operations, new types of indexes to help accelerate lookups, and various new tables used to manage metadata pertaining to the various types of GIS data you may need to store.

I'm not going to list every available operation in this book, only the most important things you need to know to get started. At last count, however, there are more than 300 different functions in the last published OGC standards.

OGC What?

The OGC standards are the recommendations set by the Open Geospatial Consortium. They define a common API, a minimum set of GIS–SQL extensions, and other related objects that any GIS-enabled database must implement to be classified as OGC compliant. Because of the diversity of GIS and their data, these standards are rigorously enforced. This enables nearly every bit of GIS-enabled software on the planet to talk to any GIS-enabled database and vice versa using a common language.

Note that when selecting a database to use, there are many that claim to be spatially aware but are not OGC compliant. Prime examples are MS SQL and MySQL.

In general, MS SQL features the OGC-ratified minimum GIS–SQL and functional implementation, but its calling pattern varies significantly from most GIS software. MS SQL also features changes to column names in some of the metadata tables, which means most standard GIS software cannot talk to a MS SQL server. Note also that MS SQL didn't add any kind of GIS extensibility until 2008, and even in the newer 2008 R2 and 2012 versions, the GIS side of things is still not completely OGC compliant.

MySQL has similar restrictions, but also treats a number of core data types very differently, often leading to rounding errors and other anomalies when performing coordinate conversions. You can find the full list of OGC standards documents on the OCG website at http://www.opengeospatial.org/standards/is.

A good place to look for information comparing various databases is on the BostonGIS website at http://www.bostongis.com/?content_name=sqlserver2008r2_oracle11gr2_postgis15_compare#221.

There are also a number of other good starter articles on the site. The downside is that the site is cluttered and sometimes very hard to read.

The Metadata Tables

All OGC-compliant GIS databases must support two core metadata tables called **geometry_columns** and **spatial_ref_sys**. Most GIS-enabled software will use the existence of these tables to determine if it is talking to a genuine GIS database system. If these tables don't exist, the software will often exit.

A good example of this was with early versions of MySQL where the table names were reserved by the database engine, but did not physically exist as tables. This would cause the MapInfo application to attempt to create the missing tables, but it would receive an error on trying doing so, thus preventing the database from being used correctly by the software.

The **geometry_columns** table is used to record which table columns in your database contain geospatial data along with their data type, coordinate system, dimensions, and a few other items of related information.

The **spatial_ref_sys** table holds a list of known spatial reference systems, or coordinate systems as they may be better known. These coordinate systems are what define geographic locations in any GIS database; they are the glue that allows all the functionality to work together flawlessly, even with data that may have come from different sources or been recorded using different geographic coordinate systems.

The entries in the **spatial_ref_sys** table are indexed by a number known as the EPSG ID. The EPSG, or European Petroleum Survey Group, is a working group of energy suppliers from the oil and gas industry who confronted a common problem that arose when surveying the world's oceans for oil reserves: positioning on a global scale. Some companies used one scale, others used a different scale; some used a global coordinate system, while others used a local one.

The group's solution was to record the differences between each scale and the information required to convert from one scale to another reliably without any loss of precision.

Today, every GIS database that claims to be OGC compliant includes a copy of this table to ensure that data conversions from one system to another are performed with as much accuracy as possible.

We'll cover the actual coordinate systems a little later in the book. For now, all you really need to be aware of is that if the **spatial_ref_sys** table does not exist or has no data in it, you will be unable to accurately map or make real-world translations of any data you possess.

Also note that it is possible to save space by removing unnecessary entries from this table. If your data only ever uses two or three different coordinate systems, it's perfectly acceptable to remove the rest of the entries to reduce the size of the table. This can be especially useful when working with mobile devices.

If you only work with data in your own range of values, arguably there can be no data in the **spatial_ref_sys** table at all. I would, however, caution you against removing the table entirely. As previously mentioned, most GIS software will look for the presence of this and the **geometry_columns** table to signify the existence of a GIS-enabled database.

What's Actually in the Metadata Tables?

The **geometry_columns** table holds data pertaining to your data and has the following fields:

f_table_catalog	The database name the table is defined in.
f_table_schema	The schema space the table is defined in.
f_table_name	The name of the table holding the data.
f_geometry_column	The name of the column holding the actual data.
coord_dimension	The coordinate dimension.
srid	The spatial reference ID of the coordinate system in use.
type	The type of geometry data stored in this table.

The **catalog**, **schema**, and **name** fields are used in different ways by different databases. Oracle Spatial, for example, has a single **geometry_columns** table used for the entire server, so the **catalog** field is used to name the actual database. Postgres, however, stores one **geometry_columns** table per database, so the **catalog** field will usually be empty. On the other hand, the **schema** field is used in both Postgres and MS SQL. In Postgres, the field is usually set to **public**, whereas in MS SQL it's normally set to **dbo** for the publicly accessible table set.

The table name and column name are pretty self-explanatory. The coordinate dimension in most cases will be **2**, meaning that the coordinate system has only x-coordinates and y-coordinates. Postgres and Oracle Spatial do have 3-D capabilities, but I've yet to see them used very much outside of very specific circumstances, and I've never seen a **coord_dimension** field set to anything other than **2**.

We'll cover the **srid** field in just a moment. The **type**, however, needs further explanation.

Database Geometry Types

Any OGC-compliant database has to be able to store three different types of primitives. They are:

- point
- line
- polygon

The names themselves are fairly explanatory. A point is a single *x*, *y* location. A line is a single segment connected by two *x*, *y* end points. A polygon is an enclosed area where a number of *x*, *y* points form a closed perimeter.

However, the three base types are not the only geometry types you'll work with. There are variations such as:

- linestring
- multilinestring
- multipolygon

Plus a few others that are rarely used.

A linestring can be thought of as a collection of line objects where each point, except for the start and end points, is the same as the start or end point of the adjacent line. For example:

1,2 2,3 3,4

would be a linestring that starts at 1,2, goes through two segments, and ends at 3,4.

A multilinestring can be thought of as a collection of linestrings. For example:

(1,2 2,3 3,4) (6,7 7,8 8,9)

would be two linestrings running from 1,2 to 3,4, and from 6,7 to 8,9, each consisting of two segments. The two linestrings would have a gap between them.

A multipolygon, as the name suggests, is a collection of polygons, but with a twist. Polygon definitions cannot overlap if they are in the same graphical object. This is illustrated in Figures 3 and 4.

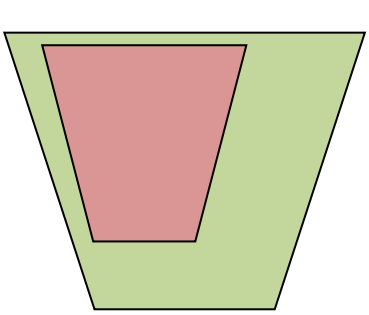


Figure 2: Valid Multipolygon

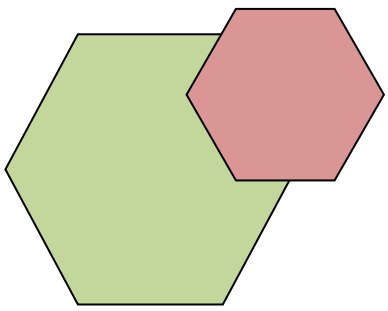


Figure 3: Invalid Multipolygon

A multipolygon must contain at least one polygon that encloses all other polygons in the set. This is known as the **outer ring**. Within this boundary, the other polygons often form holes in the outer ring. This is used for building plans with courtyards, road layouts with roundabouts, anything where an enclosed section needs to be removed from the internal area of the defined shape.

Many spatial databases, however, will define even single polygons as multipolygons. This is done so that it's easy to insert cutouts if needed at a later time.

What Types Should I Use for My Data?

The data types you use depend what your data is representing. If you have a series of locations representing shops, you'll most likely just want to define those as points. If, on the other hand, your data represents roads between those points, a multilinestring is probably a better choice. If you want to mark the building outlines of each shop, you'll want to use a polygon or multipolygon depending on the complexity of the structure.

There are no hard and fast rules for data types. You only have to keep in mind that if you don't use a data type appropriate for the operations you expect to perform, you're almost certain to end up with errors in any calculations you do.

Think back to our shops. If you're searching for the largest one, you need to test for area, and you can't test for area using a single point. On the other hand, if all you want to do is provide a searchable map for a customer to find his or her closest shop, you don't need to store more data than you need, so a simple point will do.

Enough of data layout for now. We'll come back to it in a while. Let's continue with the metadata tables.

Metadata Tables, Part 2

As mentioned previously, the **spatial_ref_sys** metadata table holds conversion data to allow conversions from one coordinate system to another.

Each entry in this table contains specific information such as units of measurement, where the origin is located, and even the starting offset of a measurement.

Most of us are familiar with seeing a coordinate pair such as this:

    54.852726, -1.832299

If you have a GPS built into your mobile phone, fire it up and watch the display. You'll see something similar to this coordinate pair. Note that on some devices and apps, the coordinates may be swapped.

This coordinate pair is known as latitude and longitude. The first number, latitude, is the degrees north or south from the equator with north being positive and south being negative. The second number, longitude, is the degrees east or west of the Prime Meridian with west being negative and east being positive. The correct geospatial name for this coordinate system is **WGS84**. Its SRID number is **4326** in the **spatial_ref_sys** table.

We'll come back to the different coordinate systems and why they exist in just a moment. For now, let's continue with the description of the spatial reference table. The **spatial_ref_sys** table has the following fields:

srid	The spatial reference number as defined by the OGC standards.
auth_name	The authenticating body for this SRID, usually the EPSG.
auth_srid	The SRID as defined by the authenticating body, which is normally the same as the SRID defined by OGC standards.
srtext	The definition text used to map the spatial difference in projcs format.
proj4text	The definition text used to map the spatial difference in proj4 format.

Everything in the spatial reference table is straightforward types for integers and strings. The **srtext** and **proj4text** have different meanings depending on what software is reading them.

The **srtext** field holds information for the projection, ellipsoid, spheroid, and other essential information that allows any software to be able to translate from one coordinate set to another. We'll cover this a little more later, but a complete description of everything you will find in this field is well beyond the scope of this small book. In fact, the smallest book I've seen describing the basics was over 500 pages!

The **proj4text** field serves a similar purpose but is used by applications using the open source Proj.4 library.

Proj.4 and Geos were two of the first open source libraries to be used by many different spatial databases and GIS applications. These two libraries are now used in close to 100% of all commercial and open source software used for any kind of spatial or GIS work. Both libraries are still actively maintained and are available for every platform you would expect to work with. We'll meet them again later when we take a brief look at some of the GIS software available for the .NET developer.

For now, all you need to be aware of is that in order to support different spatial coordinate systems, you must have entries in the **spatial_ref_sys** table.

As previously mentioned, you don't need every entry in the table; you can get by using only the SRIDs that your geometry, database, and software use. Since I live in the U.K., I typically use:

> OSGB36, SRID: 27700—Ordnance Survey, meters with false offset at origin.

and

> WGS84, SRID: 4326—Worldwide latitude/longitude, degrees with minute/hour/seconds offset, origin at 0 degrees latitude (the equator) and 0 degrees longitude (the Prime Meridian).

For other territories, you can import the entire table and see which works best, or you can look up your territory on the EPSG site at http://www.epsg-registry.org/ and grab only the definitions you need. If you are using Postgres or PostGIS as your spatial database, the **spatial_ref_sys** table is populated in a database template with all the known SRIDs

available when you install the database. Creating your own databases is simply a matter of using this template to have a fully populated table from the start.

One note of caution before we move on: some databases, while they do support the **geometry_columns** and **spatial_sys_ref** metadata tables, don't create them by default. MS SQL 2008 is noted for this; it uses its own methods for storing spatial metadata. You may find that in some cases you will be required to create some of these tables manually before you can use your database. Additionally, you may also find that some databases create the tables but use a slightly different naming convention, especially for the **geometry_columns** table. For this reason, it's always better to use the official OGC-compliant spatial SQL command set (which can be downloaded from http://www.opengeospatial.org/standards/sfs) to manipulate the data in these tables, rather than trying to manipulate the entries directly.

Coordinate and Spatial Location Systems

Before we can get onto the technical fun stuff and start to play, we have to cover a little more theory. You must understand why all these different SRIDs and coordinate systems exist.

I'd like to send you merrily on your way into your first GIS adventure right now and say this stuff really doesn't matter; however, the truth is I can't and it does matter. In fact, it matters a great deal.

If you don't comprehend this coordinate stuff correctly, it's possible to map an automobile's track as being in the middle of the Atlantic Ocean. While this may not matter for the application you're working on—you may be looking at a general overview of customer dispersal, for example—you should still try to make sure your application is as accurate as it can possibly be.

So the answer to the million-dollar question, "Why do we have to deal with all this coordinate stuff?" boils down to one thing, and one thing only:

> *The Earth is not flat.*

There, I said it. And all naysayers out there who still believe it is need to build themselves a top-notch GIS and check it out.

Jokes aside though, it's the fact that our planet is a sphere that causes all these coordinate system headaches. To make matters even worse, our humble home is not even a perfectly round sphere. It's slightly elongated around its axis, a little like a rugby ball, but not quite as pronounced. This causes further complications because the math we need to use as we look at positions closer to the poles must compensate for the differences in the Earth's curvature.

Degrees, Minutes, and GPS

Okay, so how exactly do we deal with this curvature? There MUST be one measurement that makes sense throughout the whole globe, right? If not, then how on Earth do airplanes

and ships navigate from country to country without getting lost or having to keep track all of these different SRIDs?

You'll be pleased to know there is, but it's not as straightforward as just mapping an *x* position and a *y* position at a certain place on the globe.

If you look at any geography textbook or world map, you'll see the Earth is divided into rectangles. These rectangles are formed from the lines of latitude and longitude that make up our planet's wireframe model. It looks something like the following:

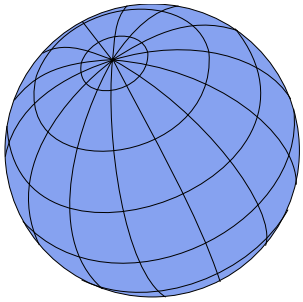


Figure 4: Earth's wireframe model

Each horizontal and vertical line represents one or more whole degrees depending on the scale factor being used. Minutes are then used to offset the position within that grid square.

When we express a latitude of 50° 25' 32" N, what we are actually saying is 50 degrees latitude, plus 25 minutes and 32 seconds north into that square, in simple terms. There's a little more complexity to it if truth be told, but unless you're navigating the high seas or piloting a commercial airliner, you're probably not going to need to go into that much detail.

The same works for longitude. Everything is expressed as a positive number, so west of the Prime Meridian is suffixed with a W, and everything to the east is suffixed with an E. Combining these with the north and south longitude designations divide the planet into four quadrants of 180 degrees each.

How is this of any relevance to the GIS developer?
If you're looking to retrieve the data from any commercial-grade GPS, particularly those built into mobile phones, you'll almost always come face to face with the National Marine Electronics Association and its standards for electronic navigation devices to communicate, known as the **NMEA 0183** standard. Opening the GPS port on just about any device will produce a constant stream of data that looks very similar to the following:

```
$GPGGA,092750.000,5321.5802,N,00630.3372,W,1,8,1.03,61.7,M,55.2,M,,*76

$GPGSA,A,3,10,07,05,02,29,04,08,13,,,,,1.72,1.03,1.38*0A

$GPGSV,3,1,11,10,63,137,17,07,61,098,15,05,59,290,20,08,54,157,30*70

$GPGSV,3,2,11,02,39,223,19,13,28,070,17,26,23,252,,04,14,186,14*79
```

This data stream is the navigation data emitted by the GPS circuitry in the device in response to what it's able to receive from the GPS network orbiting the Earth. We'll come

back to this in more detail in a later chapter. For now, I'd like to draw your attention to the first line of this data, specifically the following entries:

5321.5802,N and **00630.3372,W**

These are the GPS' current location expressed as degrees and minutes. Deciphering them is not hard once you get used to it, but it can be a little strange at first.

The format of the string is **DDMM.mmmm** for the latitude (vertical) direction and **DDDMM.mmmm** for the longitude (horizontal) direction.

Starting with the north (latitude) measurement in the string, the first two digits are the number of degrees, and the remaining numbers are the minutes. The numbers after the decimal point are fractions of a minute. This gives us:

53 degrees, 21.5802 minutes north

For the longitude measurement, the first *three* digits are the number of degrees, and the remaining digits are the minutes. All the numbers after the decimal are fractions of a minute. This gives us:

6 Degrees, 30.3372 minutes west

Because this data is string data, it's essentially an exercise in cutting the string at specific points to derive the values you want. Once you have them, the math to convert them to the more familiar latitude and longitude (if you remember that was WGS84) format is very simple.

First, you need to separate the first two digits from the latitude string and the first three from the longitude. This gives us the following:

53 and **21.5802** for the north direction

006 and **30.3372** for west

Because there are 60 minutes in a degree, we must divide the minutes digits by sixty to find what fraction of a degree they are, and then combine them with our whole degrees. So, for our latitude:

53 + (21.5812/60) will give you **53.359686** degrees.

And for our longitude:

6 + (30.3372/60) will give you **6.505620** degrees.

You get simple positions from the numbers. To finish the conversion, you need to apply the north and west directions as positive or negative numbers. The easiest way to manage which directions are positive or negative is to change any west or south measurements to negative. So with our numbers, the final coordinates in WGS84 latitude and longitude are:

53.359686, -6.505620

WGS84 is a global coordinate system standard, and while it is widely used, using it for everything can cause some problems. Because WGS84 is designed to cover the globe, it's designed also to be very lenient with the curvature of the planet. Think back to the wireframe globe in Figure 4. Notice the shape of the rectangles as they near the top of the globe.

You can see in the diagram that the rectangles become longer and narrower. This stretching also has to be accounted for in the coordinate system. Over long distances, it can cause rounding and deviations to occur in your data.

If you're dealing with a territory where you only have a defined area of operation, using a coordinate system more suited to that area is the preferred way of working. As I mentioned previously, for me here in the U.K. it's often better for me to convert these WGS84 coordinates to OSGB36 before storing them in my database. As we'll see later when we start looking at spatial SQL, your GIS database can do this on the fly when set up correctly.

That's pretty much all you need to know as a developer. There's much deeper stuff you can dig into such as spheroid and airy calculations, geodetic measurements, and a lot of that trigonometry stuff from school. The fact is that your GIS database and many of the tools you'll use will actually do the vast majority of the heavy lifting for you. So while having a good knowledge of the actual formulas used by the systems and the Proj.4 strings may be interesting, I assure you of one thing: it will end up giving you a brain ache.

In the next chapter, we start to move onto more interesting things, starting with the software we'll be using.

Chapter 2 The Software

Having a well-designed GIS database is great, but what software do you need aside from that?

Unless you're doing everything from scratch, you'll need some kind of editing application, some way to load your data, and most likely some kind of real-time data too.

The major problem is expense. You will quickly find that GIS software is probably one of the most expensive software markets on the planet. Dollar for dollar, the overall cost for most of these applications vastly outweighs your typical yearly operating system site license costs for a small office—often for just one user in one app for 6 months.

Fortunately for us, there is also a huge open source and free software movement around GIS mostly operated and managed by the Open Source Geospatial Foundation (OSGeo).

The OSGeo website at www.osgeo.org is the main hub for finding links to all the open source and spatial tools available in the market today, as well as many links to tutorials, news, and paid-for providers. They are a sponsor funded organization, and rely on groups using the software to improve it and feed it back into system.

For those companies that don't like open source and require service and support contracts, many of the open source offerings available do have such packages available for a small cost.

Let's look at some of the choices available.

Database Software

Postgres and PostGIS

This combination is to the open-source GIS scene what the godfather is to the mafia. It's the granddaddy of all GIS databases. It's fully OGC compliant, absolutely rock solid, time tested, and is supported by every bit of GIS software on the planet.

Those who know their databases will know that Postgres has been around for a very long time. It was originally a University of California, Berkley product started in 1986 by a computer science professor named Michael Stonebraker. In 1995, two of Stonebraker's students extended Postgres to SQL, and in 1996 their innovation left the classroom for the world of open source.

Refractions Research realized that Postgres had enormous potential, and in 2001 set about making an open source add-on for servers to give them full geographic and spatial

capabilities, ultimately producing PostGIS. From there, it's grown into a top-class database system for enterprise and shows no signs of slowing down.

MySQL

Originally developed as a simple-to-use open source database from the beginning, MySQL has included basic geometry types since at least v3.23. They may have been present earlier, but there is no documentation for them prior to 3.23, and no mention of them in the history of the database.

Version 3.23 documentation clearly states that the database is not fully OGC compliant. In particular, the **geometry_columns** metadata table is not supported, and many of the standard functions are renamed to be prefixed with a G—**GLength**, for example, so as not to cause issues with the standard **Length** function. The level of support for GIS across different versions of MySQL is questionable.

In more recent versions—I'm reading the version 5.6 documentation as I type this—the core engine does seem to be more OGC compliant, and I certainly know of people who use it as the central component in some complex GIS. Given that this is one of the few systems that ships with support for GIS operations, there's no need to install third-party components to spatially enable it.

MySQL is a very capable and fast system. It's also incredibly easy to administrate and has enormous support in the community despite having been recently acquired by Oracle as part of its buyout of Sun Microsystems. Its future is still a little uncertain, but one thing is sure: it will remain at the center of most LAMP and WAMP open source web stack installations for some time to come. You can learn more about MySQL at www.mysql.com.

SQL Server

Since this book is intended for .NET and Microsoft developers, I'm not going to delve into SQL Server too much as most readers will know a lot of the capabilities of the system already.

GIS functionality in the core product is a relatively new thing that was not fully introduced until SQL Server 2008. Prior to this, there were a few unofficial third party add-ons that spatially enabled SQL Server 2003 and SQL Server 2005, but these never really delivered. I remember trying an add-on for SQL Server 2005 that repeatedly crashed the server only when certain functions were called!

Even though SQL Server 2008 has GIS functionality baked in, it is probably the most non-OGC compliant OGC compliancy I've seen in any product.

Let me explain: SQL Server 2008 implements all the functionality required in the OGC specifications, functions such as **ST_GeomFromText** or **ST_Polygonize** and so on. But because SQL Server is a CLR-based assembly, it doesn't allow functions to be accessed in the same way. I'll discuss the SQL more in-depth later; for now, consider the following:

Standard OGC-compliant SQL

```
SELECT id,name,ST_AsText(geometry) FROM myspatialtable
```

SQL Server 2008 OGC-compliant SQL

```
SELECT id,name,geometry.astext() FROM myspatialtable
```

This minor difference causes all sorts of issues. In particular, it means that any software using SQL Server 2008 as its backend needs specialized data adapters (usually based around ODBC) to translate calls to the server in an OGC-compliant way. In fact, most GIS software has only just recently started to provide built-in support via ODBC.

One positive aspect for .NET developers using SQL Server is direct support in .NET via the Entity Framework and its **`Geometry`** and **`Spatial`** classes. If you're working solely on the .NET platform, there is a strong argument for not needing to use anything other than SQL Server. If, however, you need access to GIS in general and the underlying SQL to manipulate it, SQL Server is not the best choice.

The official SQL Server website is www.microsoft.com/sqlserver/en/us/default.aspx.

SQLite and SpatiaLite

SQLite is not strictly a database server, but one of the new generation single-file database engines designed to be embedded directly into your application. SQLite has amazing support on a massive number of platforms, and is possibly one of the most cross-platform kits I've had the pleasure to use.

Compared to the big three already mentioned, SQLite is a relative newcomer to the scene, but it runs remarkably well and is incredibly efficient, especially on mobile platforms. In fact, it's so good on mobile platforms that it's been chosen as the database engine of choice on Android devices and Apple's iOS, as well as featuring full support on Windows Phone through the use of a fully managed .NET interface.

SpatiaLite, the spatial extension for the SQLite engine, is not so lucky. Its sources are available, but built binaries are only provided for the Windows platform. For any other platform you'll need to download the source and then port it to your platform of choice. While this is not difficult, the sources are all in standard ANSI C and can be a little tricky to get working, especially if you have very little native C or C++ experience.

There are binary builds available for platforms other than Windows, but these are very fragmented and often out of date. Bear in mind also that SpatiaLite, like much of the open source GIS-based software available, depends on Proj.4, GEOS, and other libraries to provide many of its advanced features. If you have to custom build SpatiaLite for your platform, you'll likely have to custom build the dependent libraries as well.

Does this put SQLite and SpatiaLite out of the picture? Not really. I have yet to find anything else that works on so many different mobile platforms with such a consistent API. While there is some work involved, building for your platform is quite simple in most cases, and certainly no more complex than the work that needs to be performed when installing Postgres/PostGIS, MySQL, or SQL Server. However, unless you need spatial capabilities that are universally mobile, SQLite and SpatiaLite are probably not worth the effort.

The SQLite website is sqlite.org. Its .NET interface is available at http://system.data.sqlite.org/index.html/doc/trunk/www/index.wiki.

The SpatiaLite website can be found at www.gaia-gis.it/gaia-sins/index.html.

Oracle Spatial

Unless you're a multimillion dollar enterprise, it's very unlikely you are going to have access to Oracle Spatial. Oracle Spatial is to the commercial world what Postgres is to the open source world.

It's big, it's hungry, it costs an arm and a leg to license, and the learning curve is probably steeper than climbing Mount Everest.

Many government agencies in the U.K. use it for their mapping and planning work, and larger companies such as oil and gas giants deploy multibillion-dollar infrastructures based around it to support their survey work. If you're in a position where you are using this, then you most likely won't be talking to the system directly; you'll already have software set up for you that manages everything the database can do. Systems built around Oracle are generally designed specifically by Oracle's consultants for a specific purpose, and have an entire toolkit built around them at the same time. Most of the software I mention in this book does not—to the best of my knowledge—have the ability to connect to Oracle Spatial; or if it does, the setup and operation of doing so is tremendously complex.

The official Oracle Spatial website can be found at www.oracle.com/us/products/database/options/spatial/overview/index.html.

What about the rest?

There are many more database packages available out there. Some support GIS out of the box, and some don't. Some of them need third-party add-ons or involve a complicated setup.

The reason for leaving others out is because there is simply not enough room in this book. If you decide to explore additional databases, you may want to check out the following:

- MongoDB at www.mongodb.org
- SpaceBase at paralleluniverse.co
- CouchDB at couchdb.apache.org
- CartoDB at cartodb.com

SpaceBase in particular looks like it could be a lot of fun. Its primary goal is to track and store online MMO-based game characters and assets in a near real-time 3-D world for multiplayer games.

GIS Desktop Software

In order to manipulate your GIS assets you need a good desktop application—preferably one that not only allows you to view and manipulate your data, but also allows you to import and export data with relative ease.

The latter point is also important because the sole purpose of some applications is to move data into and out of your system, and other applications are made only for viewing data. Applications for moving data are commonly known as ETL (Extract, Transform, and Load) packages. ETL packages are available for many database engines in general, not just for those designed to manipulate geospatial data.

Fortunately, most software allows you to do both. Starting with these packages, here are some of the more well-known ones:

ESRI ArcGIS

One of the big players in the market, ESRI, has been providing GIS and mapping software now for over 20 years. The software is like many GIS packages: quite expensive, and certainly outside the price range for most hobbyists and small and medium enterprises. ESRI does, however, offer a free product called ArcGIS Explorer Desktop that can be used to make basic maps and produce your own mapping data.

One thing to note about ArcGIS Explorer Desktop is that it can be used to look at imagery from Bing's and Google's mapping services. As you can see in the following screenshot, I've marked some features in the City Centre of Newcastle-upon-Tyne, England:

Figure 5: A Modified Existing Map in ArcGIS Explorer Desktop

You can find out more about ArcGIS Desktop Explorer and other ESRI software at www.esri.com/software/arcgis/explorer.

Pitney Bowes MapInfo

MapInfo, like the ESRI suite, is a large commercial package designed with the enterprise in mind. I know from my own experience that it's used by a lot of utilities companies such as mobile phone operators for managing their network map assets. Like Oracle Spatial, you'll rarely come across this package unless you have a very specialized management system for your geospatial data.

While it can load and work with all the common map formats and services like Bing, Google, and others, MapInfo's primary design is to handle non-standard data in large, heavily customized GIS databases. Its strength lies in its ability to be extended using its own programming language called MapBasic that is often deployed in many custom configurations. For instance, it may be deployed in a wireless service's operator consoles for showing where network faults are located, or at a delivery service for keeping track of its vehicles.

You can find more info about Pitney Bowes MapInfo at www.pbsoftware.eu/uk/products/location-intelligence/.

OpenJUMP

Now we come to the first of the open source desktop offerings, OpenJUMP. Designed from the start to be open source, it's built using the Java platform, and as expected can talk to most of the GIS databases in use today.

It allows you to load and view your own spatial data, handle shapefiles and GML files, and export maps as SVG for display on the web.

Its primary purpose is to edit mapping data in preparation for creating vector maps for web use. I've personally never used OpenJUMP, but it seems like a very capable package for creating web maps from scratch.

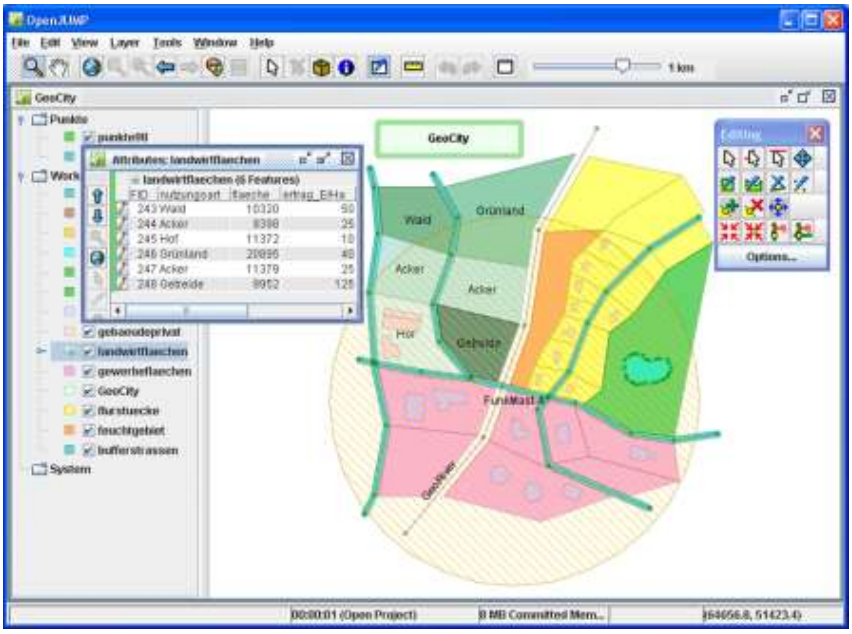


Figure 6: Using OpenJUMP

You can find more out about OpenJUMP at www.openjump.org.

Quantum GIS

There's nothing I can say that does Quantum GIS (QGIS) justice. This package can do just about anything. It's on par with applications such as ESRI and MapInfo, fully open source, and officially supported by the OSGeo Foundation.

The main application is written using Python, and as a result will run on Linux, Mac OS, Windows, and anything else that supports Python in a desktop environment.

Now on version 1.8.0, the development of Quantum GIS has built strength upon strength in the relatively short time it's been available. The extension API exposed by the system is simply amazing, and can be customized at every level—from re-engineering the main UI, to plug-ins that expose things like live GPS tracking, to the creation of brand new vector layers by applying algorithms to different layers in a package.

It comes standard in OSGeo4W, a collection of open-source geospatial software for Windows, along with Grass, MSYS, OpenEV, and many others. Backed by tools such as GDAL, pg2mysql, and many others, the only limit I've found to this package is your imagination.

Quantum is my desktop tool of choice when dealing with all the different types of data available. It can handle Postgres and all other major databases with the same ease that it imports and exports just about every known GIS file format on the planet.

It's also one of the few packages that can import and export Google Earth (KML) files for direct use with projects that make use of Google's mapping API. The current version now also includes a handy geospatial file explorer, which means you can browse and view your local file system resources without needing to fire up the full-blown GUI.

In the following screenshot, you can see QGIS loaded with a multilayer vector map (an Ordnance Survey Strategi map of the U.K.) zoomed in on Newcastle upon Tyne City Centre:

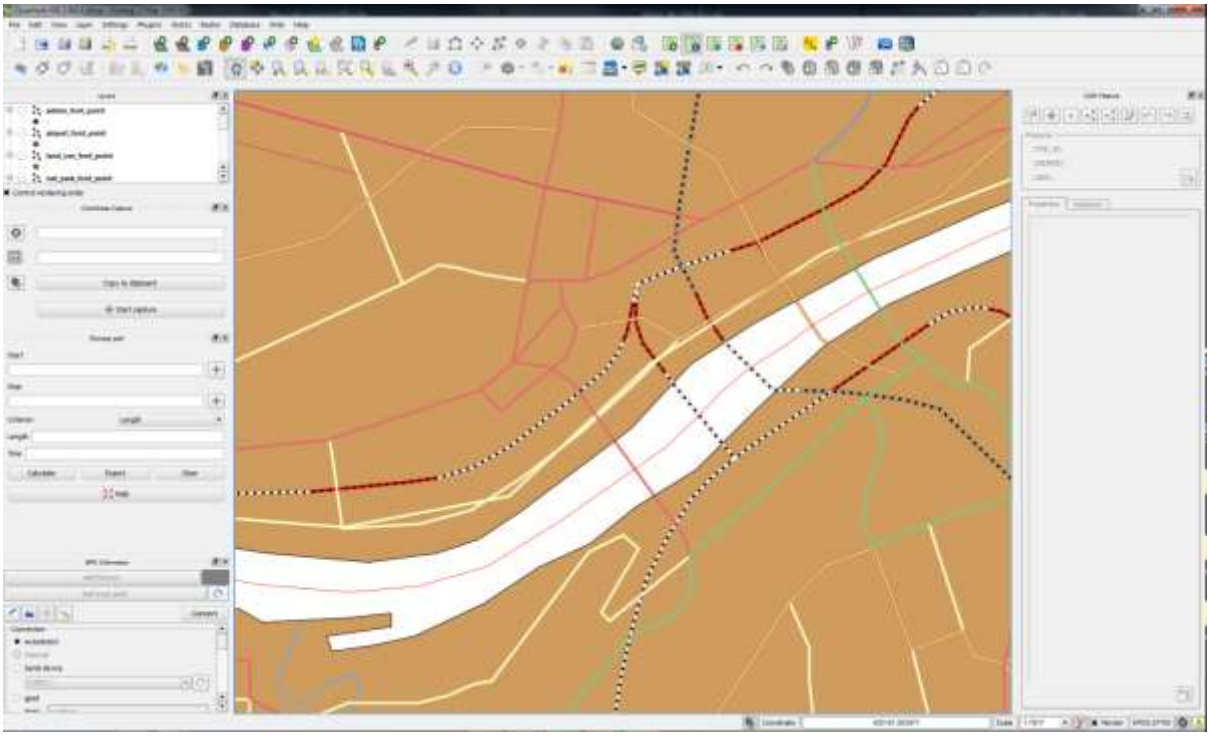


Figure 7: Multilayer Vector Map in QGIS

In this figure you can clearly see the path of the river Tyne, the local road and rail links, and even utilities such as power cables. The loaded map set, even though zoomed in, includes this data for the entire United Kingdom.

I could write an entire book about QGIS alone, but for now if you want to find out more you can do so at the official QGIS website at www.qgis.org.

MapWindow

MapWindow is designed very much to be used in a similar way to QGIS. Its main purpose is to do everything a desktop GIS application can do, with a variety of functionality.

It's also the only one written specifically for the Windows platform, designed to encompass the Windows developer community with its rich developer API and toolsets.

MapWindow is available in two versions: MapWindow 4 and MapWindow 6. MapWindow 4 is the original, first-generation C++ version, and MapWindow 6 is the latest, state-of-the-art rewrite, written entirely using C# and the standard .NET runtime.

Currently, both releases are updated and released in tandem, according to the Codeplex page for the application. This is because MapWindow 6 has yet to reach the same level of functionality as MapWindow 4. As you can see in the following screenshot, it's very similar to QGIS:

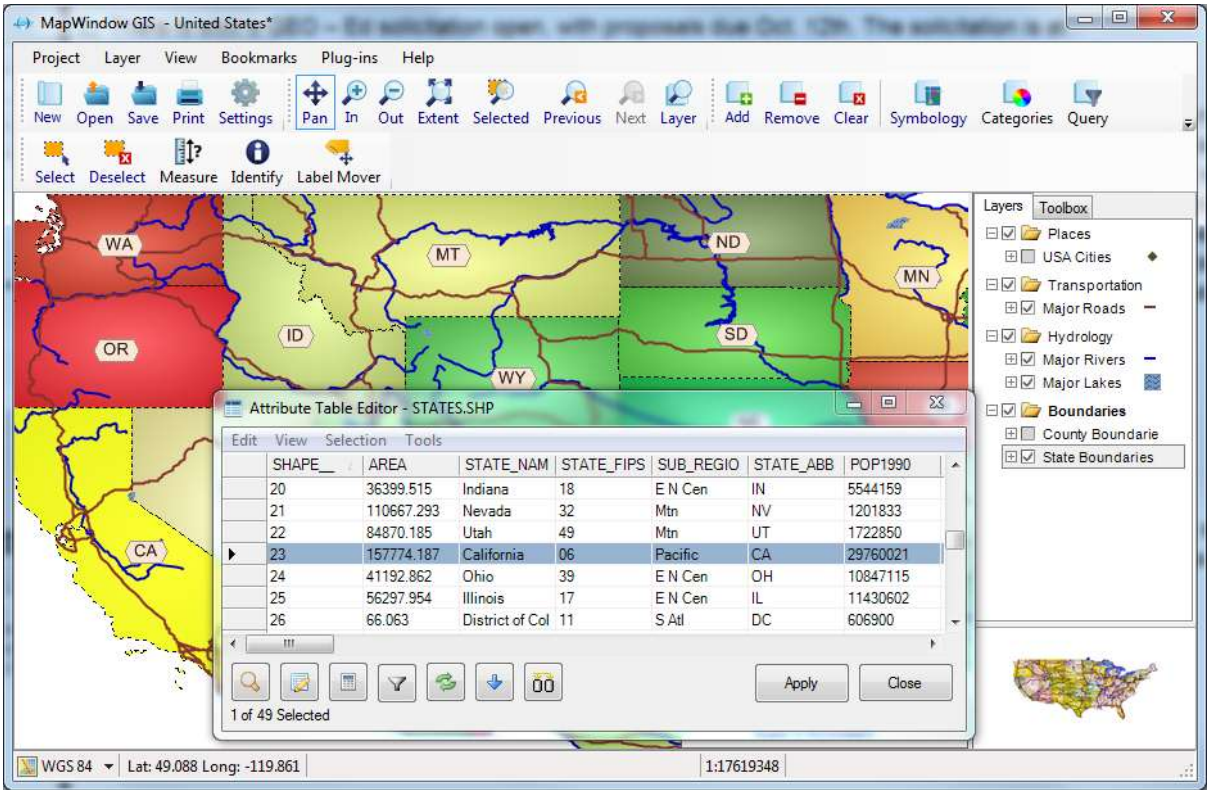


Figure 8: MapWindow GIS Interface

To find out more, visit the project home page at mapwindow4.codeplex.com or mapwindow6.codeplex.com.

GeoKettle

One more application that deserves mention is GeoKettle. While this is not a desktop GIS application in the same sense as the others, it's just as important.

GeoKettle is an ETL tool. Its primary purpose is to transform and then load data between many formats and many types of database. Originating from a package called Pentaho data suite, GeoKettle was enhanced to support industry-standard shapefiles, KML files, and the spatial characteristics of all the previously mentioned databases.

A shining example of how well done a simple-to-use open source application can be is my experience seeing many people replace highly priced applications such as Safe FME with solutions based on GeoKettle.

Written in Java, it has a plug-in architecture that is very easy to extend, making it easy to work with future file formats and databases. It can handle normal data in databases and files too, not just geospatial data. If you've ever used Microsoft Business Intelligence Development Studio, you'll feel right at home using GeoKettle as you'll notice in the following screenshot:

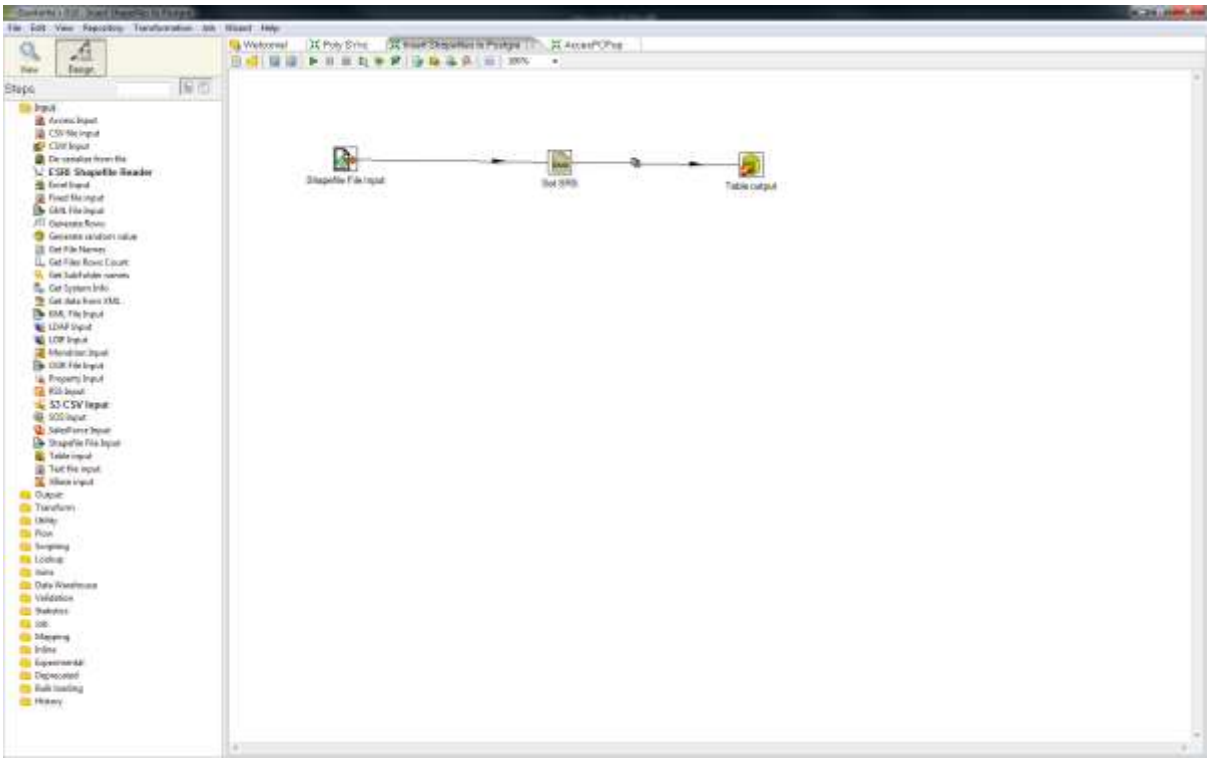


Figure 9: GeoKettle Interface

If you want to find out more, you can visit the GeoKettle website at www.spatialytics.org/projects/geokettle.

The Remaining Packages

As with database engines, there are simply too many GIS desktop packages for me to list them all. Wikipedia has a good list of geospatial and GIS software, ranging from pricey to free, at en.wikipedia.org/wiki/List_of_GIS_software, including those that I've covered here.

My two personal favorites are QGIS and GeoKettle, but I encourage you to try all that you are able to. Over the years, I've used many desktop GIS packages; some have very steep learning curves, and some you can pick up in less than five minutes. As with anything, you should pick the tool that does the job you need to perform in the best and easiest way possible.

Please also note that the applications I've listed are used predominantly in the U.K. and Europe. The popularity of applications varies all over the world. For instance, I believe that IDRISI is a popular package used in Canada. The applications listed in this section are the ones I use in my day-to-day GIS work.

As I've already mentioned, you have a ton of other stuff to take care of besides your choice of software.

Development Kits

Since this book is aimed at the .NET developer, it's only right that we include a section on the kits available for using geospatial data in your own .NET applications.

We'll cover a few practical examples later on, but for now I'll list the kits I've used or seen in use. Please note, however, that this is not an exhaustive list. The toolkits I describe are all designed for use under .NET on the Windows platform. As I've mentioned, applications like QGIS can be vastly extended, and there are many toolkits available under Linux and Mac systems that I've not yet and likely won't cover. If you're starting a project where you know you're going to be writing custom user interfaces, do your research beforehand. Instead of writing them from scratch, there's every chance you can modify an existing application to suit your needs.

MapWinGis

MapWinGis is the central GUI component behind MapWindow 4 and MapWindow 6. It's an OCX control written in C++ that can be used in any language that supports OCX on the Windows platform.

In the past, I used the original version of this component. It's been some time now since I've done any development using it. As with many of these components, it has a permanent home on Codeplex at mapwingis.codeplex.com.

It is designed to do most of the heavy lifting for you, leaving you free to concentrate on the GUI aspects of your application. Please note that it's designed for use in desktop applications, not web-based applications, and as far as I'm aware cannot be used in WPF or Silverlight.

DotSpatial

DotSpatial is a sister project of the MapWindow stable, and actually forms most of the core of the new MapWindow 6 .NET rewrite. DotSpatial also incorporates a few other Codeplex projects under its hood too, most notably GPS.Net and GeoFramework. Both are still available separately.

One thing that's worth noting about DotSpatial is that like QGIS, this toolkit has the backing of the OSGeo Foundation. As part of its kit, it also has the entire open source GIS developer library (including GEOS, Proj.4, GDAL, and many more) packaged as ready-to-use Windows DLLs for direct inclusion in your projects.

The project home page can be found on Codeplex at dotspatial.codeplex.com/.

SharpMap

SharpMap is one of the older toolkits for .NET. It has been around a little longer than DotSpatial.

It can handle most types of vector and raster data, including the NASA Blue Marble tile set for the entire globe.

According to its documentation, the SharpMap library supports both desktop and web-based projects (the later via the use of the AJAX Map control). It can also create custom thematic map styles by combining many different types of overlay.

The project home page can be found at sharpmap.codeplex.com.

BruTile

While not a full GIS library in the same sense as others, BruTile does one thing, and does it very well: it serves raster tiles cut up and reorganized on the fly to allow smooth scrolling and zooming of any input that the library handles.

BruTile is actually used by both SharpMap and DotSpatial to provide output support on their raster tile components. It's also used to display open street map data running inside a Silverlight map at brutiledemo.appspot.com.

BruTile can be used in any type of project, from web and Silverlight, to high-end desktop apps. It also has an adapter that allows it to be used in custom ArcGIS deployments.

The project home page is located at brutile.codeplex.com.

And There's More...

As with the other bits of software mentioned previously, there are simply many, many more available. What I've not even begun to cover here is the fact that all the major players such as ESRI and Pitney Bowes offer their own SDKs as well. In fact, a large chunk of ESRI's profit comes from the provision of GUI toolkits that are used in much the same way as MapWindow. Unfortunately, as much as I would like to, there are simply too many to cover in this short book.

The Demos

So now we get to that all-important question: what will I be using for the demos in this book?

I already have a setup of PostgreSQL with PostGIS, and most of my spatial SQL examples will be done using this. Any database management tool you have that can connect to Postgres will work. However, I will be using the one that comes provided with the server: pgAdmin.

In addition to this, I'll be using Quantum GIS to manage and display data along with a demonstration of using GeoKettle to load some data.

For the programming examples, I'll be using SharpMap in Visual Studio 2010 Professional in the C# language. The samples can be downloaded from bitbucket.org/syncfusion/gis-succinctly.

Please note that I won't be covering how to install and initially set up any of these applications. This is a fairly simple operation in most cases, and one that I'm going assume the reader of the book is familiar with. If you have any issues with installing the software, all the applications mentioned in this book have very active communities and help forums.

For those of you who are familiar with Stack Overflow, its GIS-specific site can be found at gis.stackexchange.com.

Many of the regulars there are expert GIS users who have a very deep understanding. Some parts of this book wouldn't have been possible without the help provided and replies to the questions I've asked there. I strongly recommend that anyone playing with GIS in .NET add a bookmark to the site right alongside a bookmark to the main Stack Overflow page.

Chapter 3 Loading Data into your Database

The first thing we need to do before we can begin to explore what a GIS can do is load some data in.

In this chapter, I'm going to load three ESRI shapefiles into Postgres to use with the demos later on. The first two of these will be point-based files showing the location of cities and towns in the U.K. The third file will be a polygon file showing the outlines of all the county and borough boundaries that make up the U.K.

For those of you who are not familiar with U.K. geography, the county boundaries logically divide the country into administrative regions, similar to the U.S. states or Chinese provinces.

Creating a Spatial Database

Before we can start to add any data into our system, we first need to create a database for storing the data. For the samples in this book, I'm going to create a simple three-table database rather than an entire GIS model as described earlier.

If you are working on a large enterprise application, I can't stress enough how important planning and design is in GIS database solutions. In many ways the planning part of this is substantially more important than the same steps in a normal database. Failures and alterations further down the line tend to be more pricey and more complex to fix for GIS solutions than for an average enterprise data solution.

To create the database, we'll be using the database admin tool provided with Postgres, pgAdmin. To start pgAdmin, click on the **pgAdmin III** icon on your desktop. If you don't see the icon, make sure that you installed the management tools when you installed the server.

Once you've installed the app and created an initial connection to your database server, you can start to create a database in that server connection as shown in the figures that follow.

Please note that for security reasons, I've removed server and table names from many of the figures showing pgAdmin in this book, leaving only those that are necessary for your understanding. In your use of pgAdmin, you'll see a lot more information when going through the steps I present here.

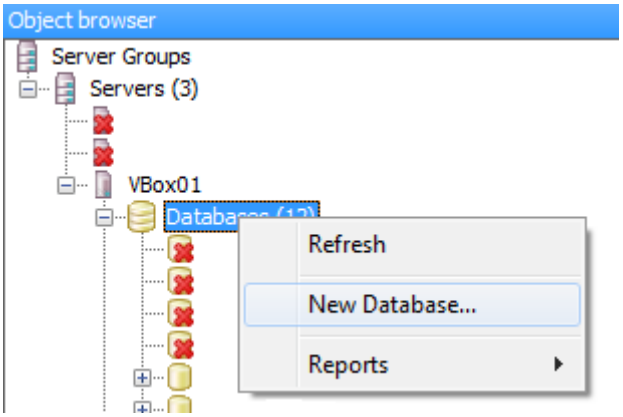


Figure 10: Creating a New Database

Right-click on the **Databases** item in your server tree and select **New Database**. This will launch the **New Database** dialog.

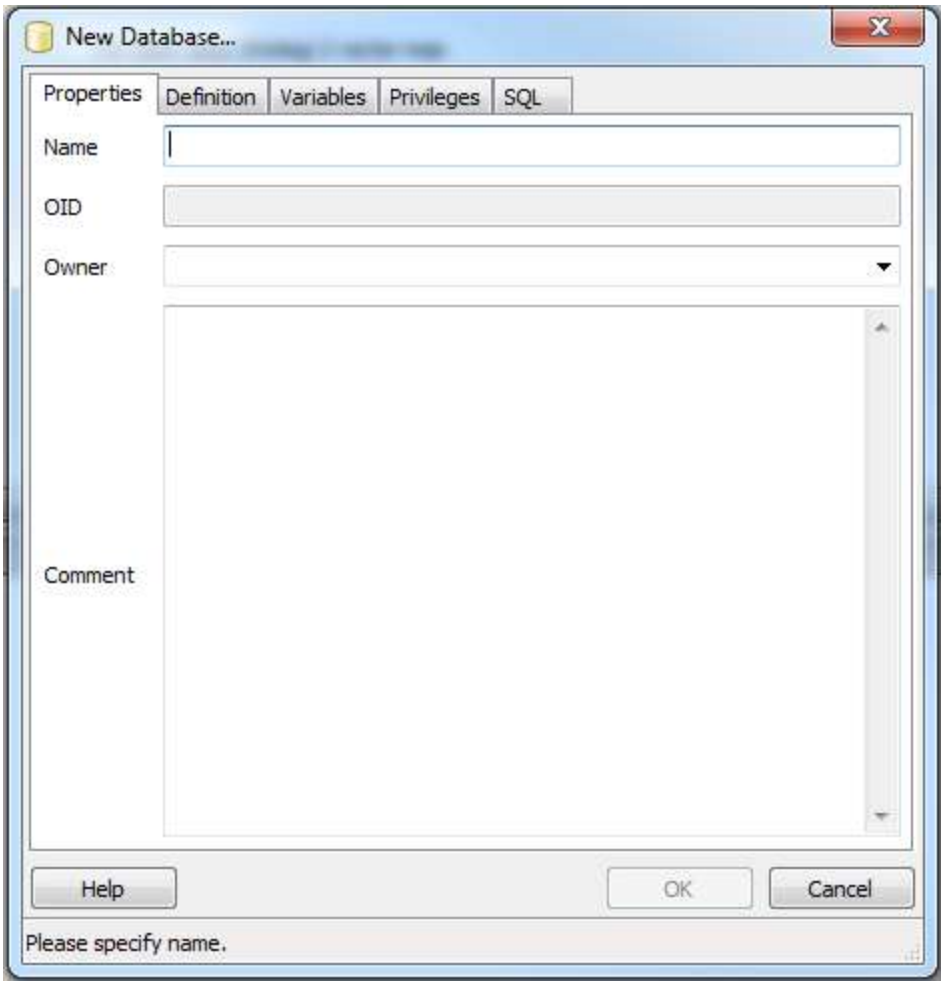


Figure 11: Naming the New Database

It's quite easy to see what needs to go where. All we need to do is give the database a name and an owner. You can fill in the **Comment** field if you wish; the rest you can generally leave with the default settings. Once you have the fields filled in, your dialog should look something like the following:

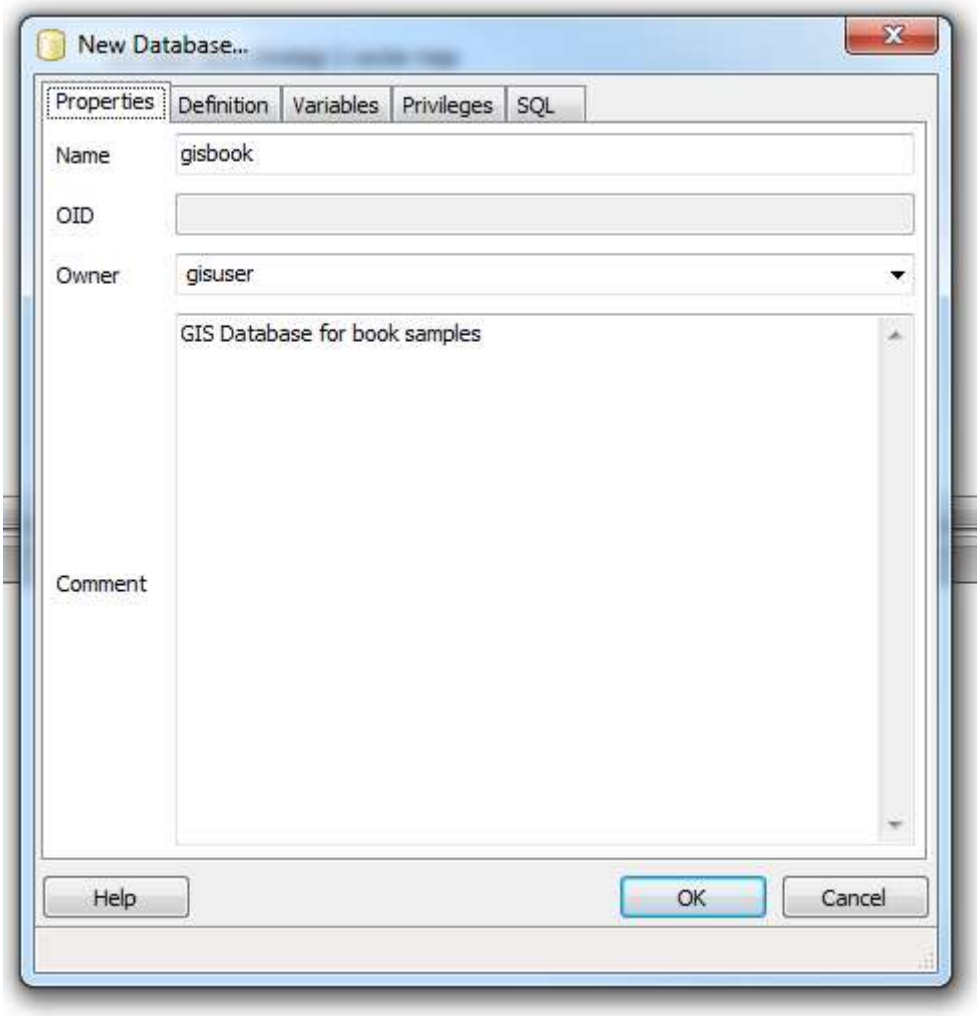


Figure 12: Completed New Database Dialog

Most Postgres installers create a template to aid in the creation of spatial database tables when using this or similar dialogs. Before we click **OK**, we need to navigate to the **Definition** tab and select the template to use as shown in the following figure:

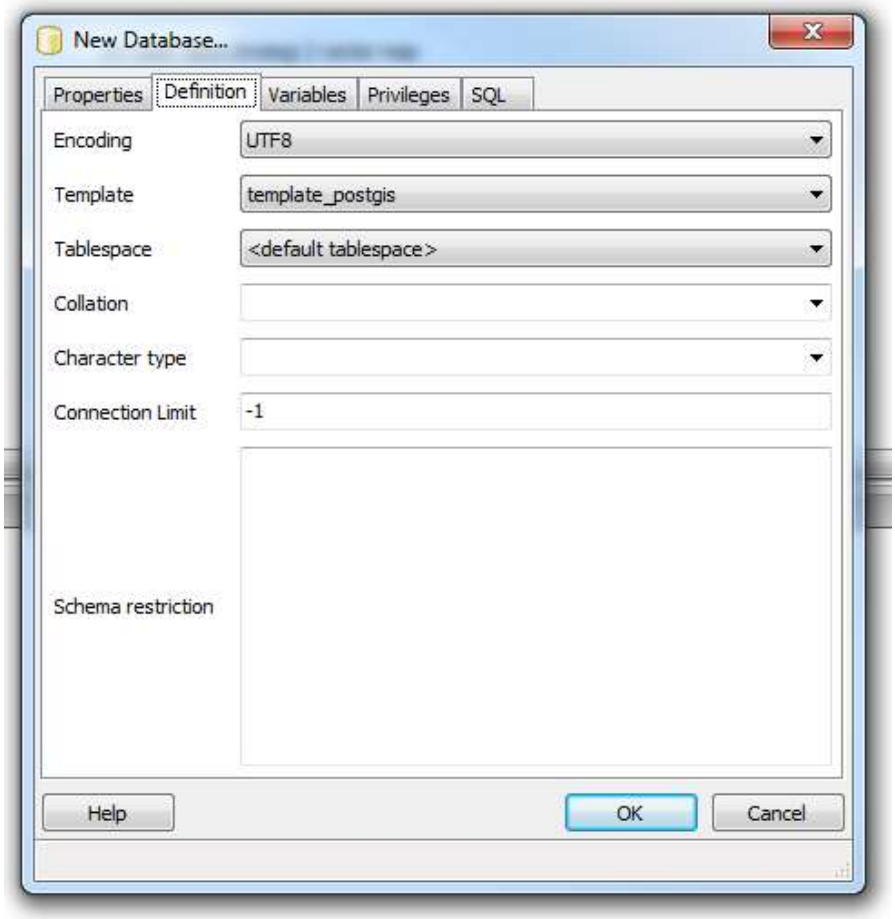


Figure 13: Choosing a Template from the Definition Tab

All the other options in this tab can be left as they are. Once you click **OK**, pgAdmin will return to the main display where you'll see your new database appear in the server tree.

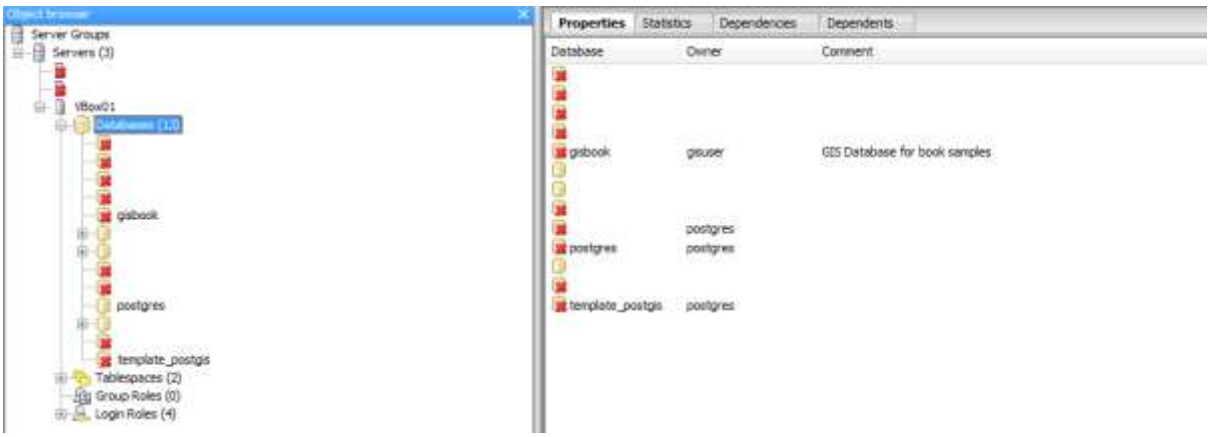


Figure 14: New Database Added to Server Tree

It's also possible to create the database by hand using standard SQL commands such as **`Create Database`** and **`Create Table`**; however, using these can be a lengthy process.

There are scripts in the Postgres **Contrib** directory (located where you chose to install Postgres) that you can load and run to create all the spatial functions and metadata tables

required. Since every installation of Postgres I've done has included pgAdmin, I've found it much easier and quicker to use the GUI. Please also note that even if you are installing your database on a platform such as Ubuntu, the pgAdmin tool can be downloaded separately from the Postgres website and installed on a standard Windows machine for managing your server.

Once the database has been created, you can expand the objects in the server tree to show the different tables and objects in your new spatial database.

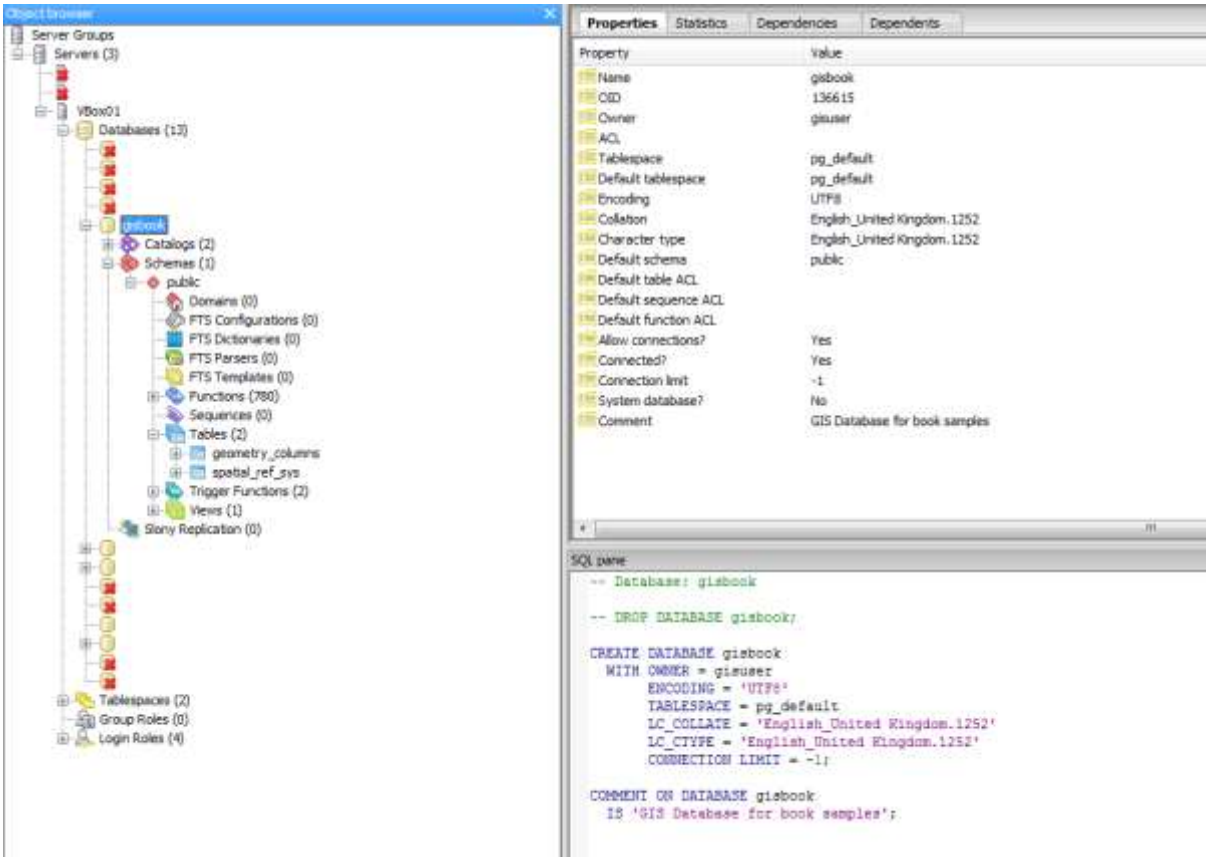


Figure 15: Exploring the New Database

A Side Note about Postgres Users

Many of you reading this will likely be accustomed to using MS SQL Server for your data tasks. Postgres, like SQL Server, supports multiple user accounts. However, you need to be careful with using the root admin account.

In MS SQL, the super user account (usually **sa**) has ultimate control over the entire database. Under Postgres, the equivalent super user account is called **Postgres**, but unlike MS SQL, the Postgres user can be prevented from interacting with other tables.

If you create all your tables using the Postgres account you won't have an issue, but if you create databases and then assign ownership of these databases to other user names you have created in your server, you might find that the **Postgres** user account is unable to work with them.

This problem will most likely arise when opening database layers in QGIS. If you create a database connection using a given set of credentials, and create the database in pgAdmin using the **Postgres** user account, you'll find that the spatial metadata tables will have **Postgres** as their owner. When this happens, QGIS will be unable to open the metadata tables and will show no layers available for you to use in the application.

The solution to this is very simple. Using pgAdmin, right-click on one of the metadata tables and select the **Properties** option as shown in the following figure:

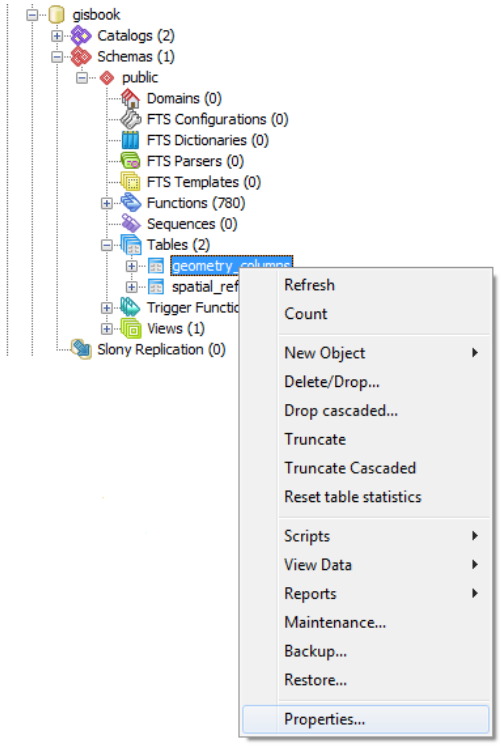


Figure 16: Editing Metadata Table Properties

The table's **Properties** dialog will appear.

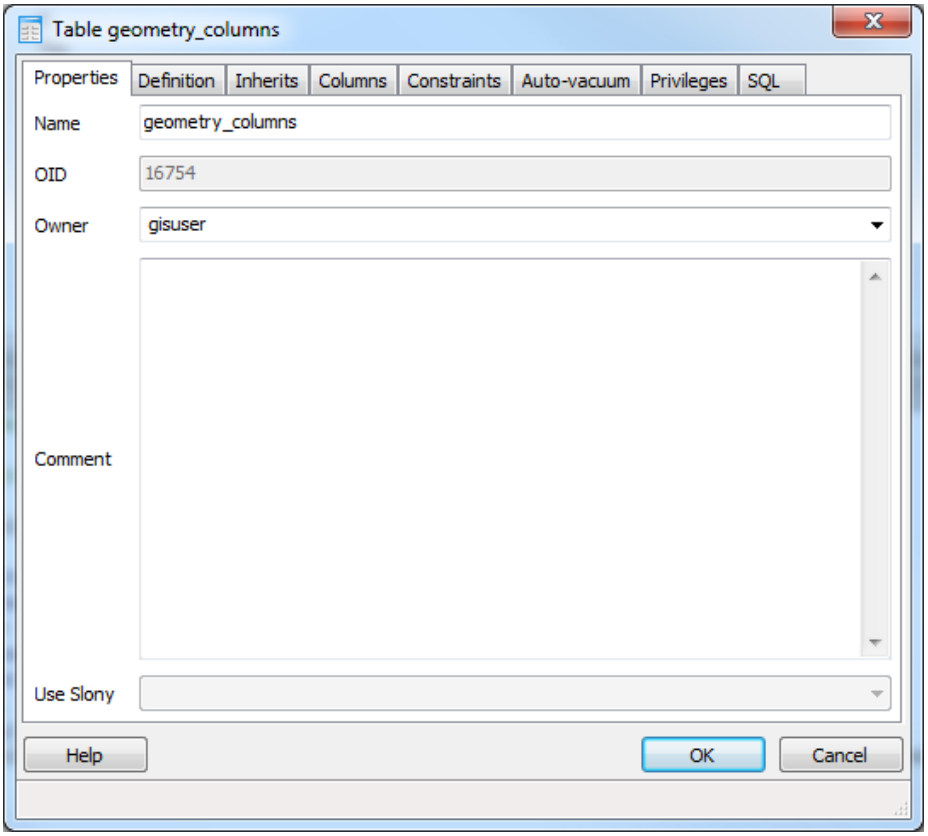


Figure 17: Editing the geometry_columns Table Properties

The **Owner** field provides a drop-down list of users defined in the server. Select the owner that you are using in your app connection.

Revisiting the Metadata Tables

If you remember from our discussion earlier in the book, we discussed the spatial metadata tables and the importance they have in the grand scheme of things.

If you've created your spatial database correctly, you should see two tables in your server tree: **geometry_columns** and **spatial_sys_ref**. Right-clicking on them and selecting **View Data** will allow you to examine what's in them as shown in the following figures.

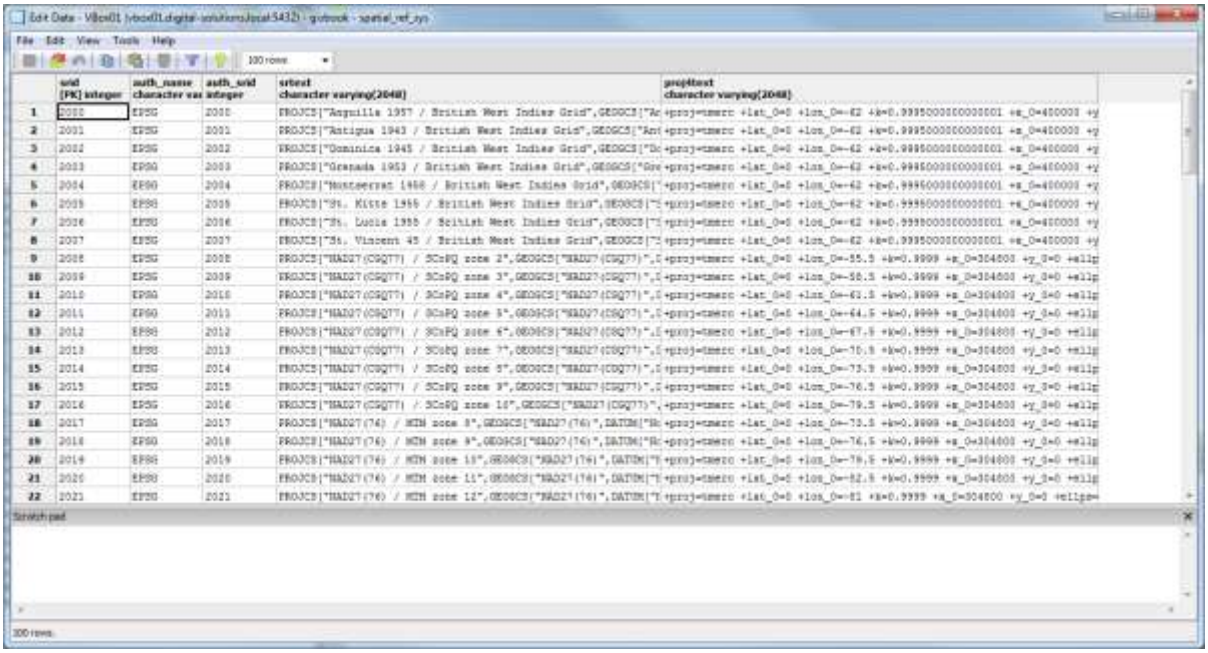


Figure 18: spatial_sys_ref Table

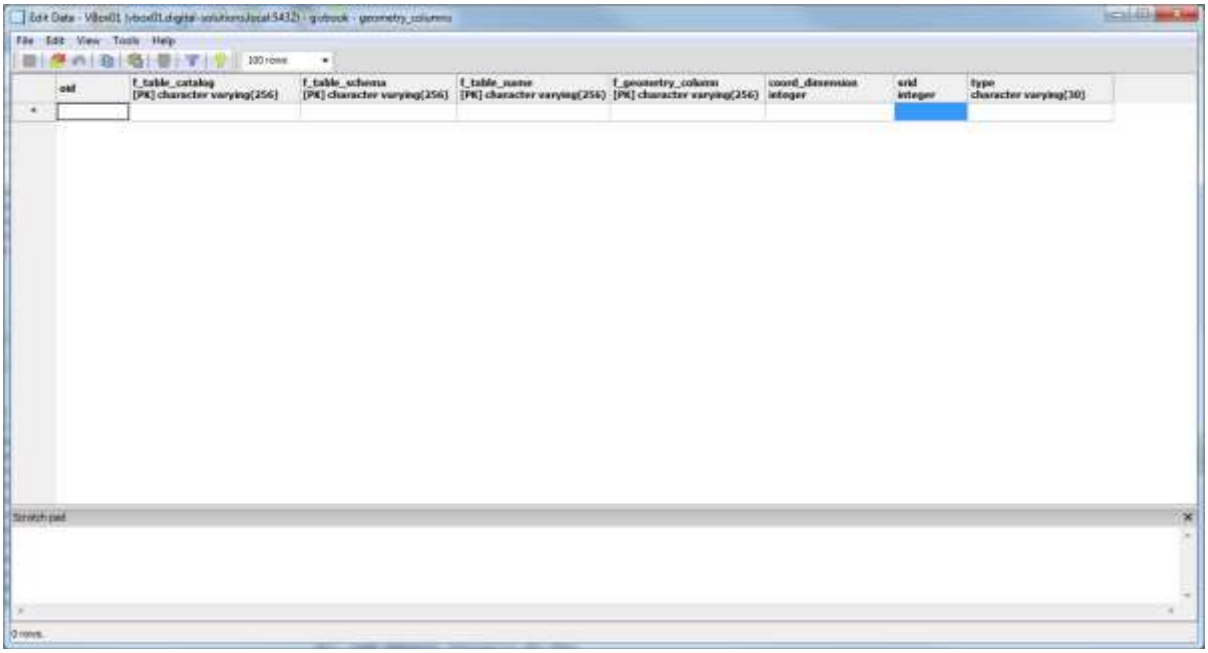


Figure 19: geometry_columns Table

As you can see, the geometry_columns table is initially empty. This will start to fill up as we load data into our database.

Loading Points Using QGIS

Quantum GIS has a great little tool built-in called **SPIT** (Shapefile to PostGIS Import Tool) whose sole purpose is to insert ESRI shapefiles into Postgres.

In practice, I have found that it gets upset easily if there's even the slightest bit of corruption or non-standard data in the shapefile you are trying to import. Despite its fragility, it remains the most used tool by QGIS users to import data into their database.

You activate SPIT by clicking the small blue elephant icon on your QGIS toolbar as shown in the following picture:

Figure 20: Activating SPIT

Once SPIT loads and displays its main interface, you should see the following:

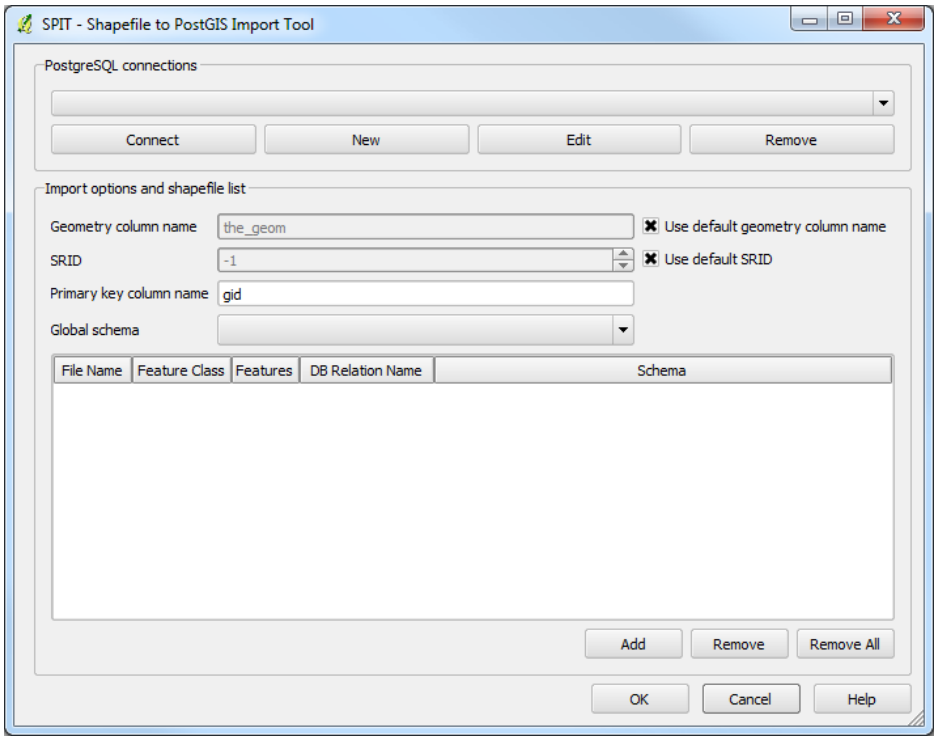


Figure 21: SPIT Interface

The interface is fairly self-explanatory. The **PostgreSQL connections** area is where you'll find any connections to your SQL databases listed. The **Import options** are for specifying things like the SRID of your data, and other options for the data import.

Your PostgreSQL connections list is shared between here and the main app. If you've already created a connection in QGIS, you'll be able to reuse it here by just selecting it from the drop-down and clicking **Connect**.

For the purposes of this exercise, however, we'll be creating a new connection to hold our data. To start, click **New** under **PostgreSQL connections**. The **Create a New PostGIS connection** dialog will appear.

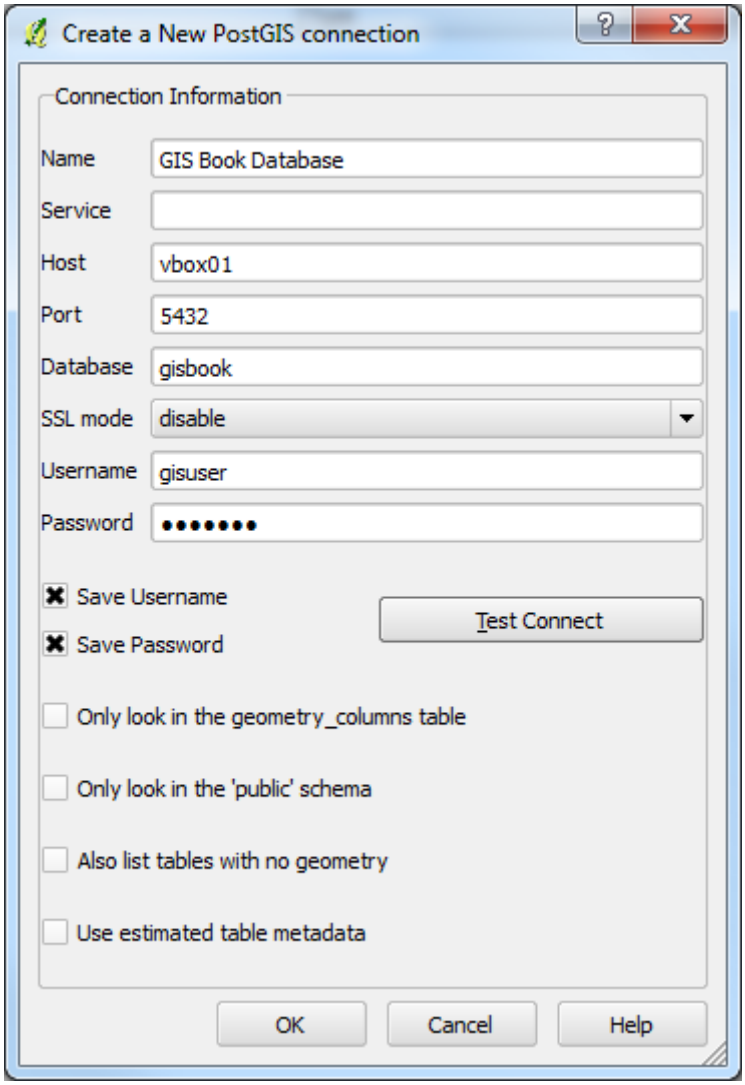


Figure 22: Creating a New PostGIS Connection

Complete the fields as shown in Figure 22, remembering to substitute your server name, database name, user name, and password as required for your own Postgres installation.

You don't have to save the password and user name, but it makes connecting easier if you don't have to type the credentials in every time.

The four deselected options are not required. They are used to control the following:

- **Only look in the geometry_columns table**: This option means exactly what it says. By default, QGIS will look at all tables in the database to see if any of them contain spatial geometry. Selecting this check box prevents this.
- **Only look in public schema**: If you use different schemas to logically divide your database, selecting this option will make QGIS only look in the **public** schema (equivalent to **DBO** in MS SQL).
- **Also list tables with no geometry**: Selecting this option will make QGIS list tables with no geographic data in the **Add Layer** dialog.

- **Use estimated table metadata**: If you have a table that is not registered in the geometry_columns table, selecting this option will make QGIS guess the data type, rather than examine the data in the table to determine the geometry type.

Once the fields are completed, click the **Test Connect** button. The test should be successful.

Click **OK** to save the connection and register it in the **SPIT** tool.

Once you return to the **SPIT** dialog, click **Connect**, and then use the **Add** button to browse and load the shapefiles for U.K. towns and cities.

You can download sample shapefiles from bitbucket.org/syncfusion/gis-succinctly.

Once you've set the other options such as the **SRID**—all files provided for these demos are in UK-OSGB36, SRID 27700—and the **Geometry column name**, your **SPIT** dialog should look similar to the following figure:

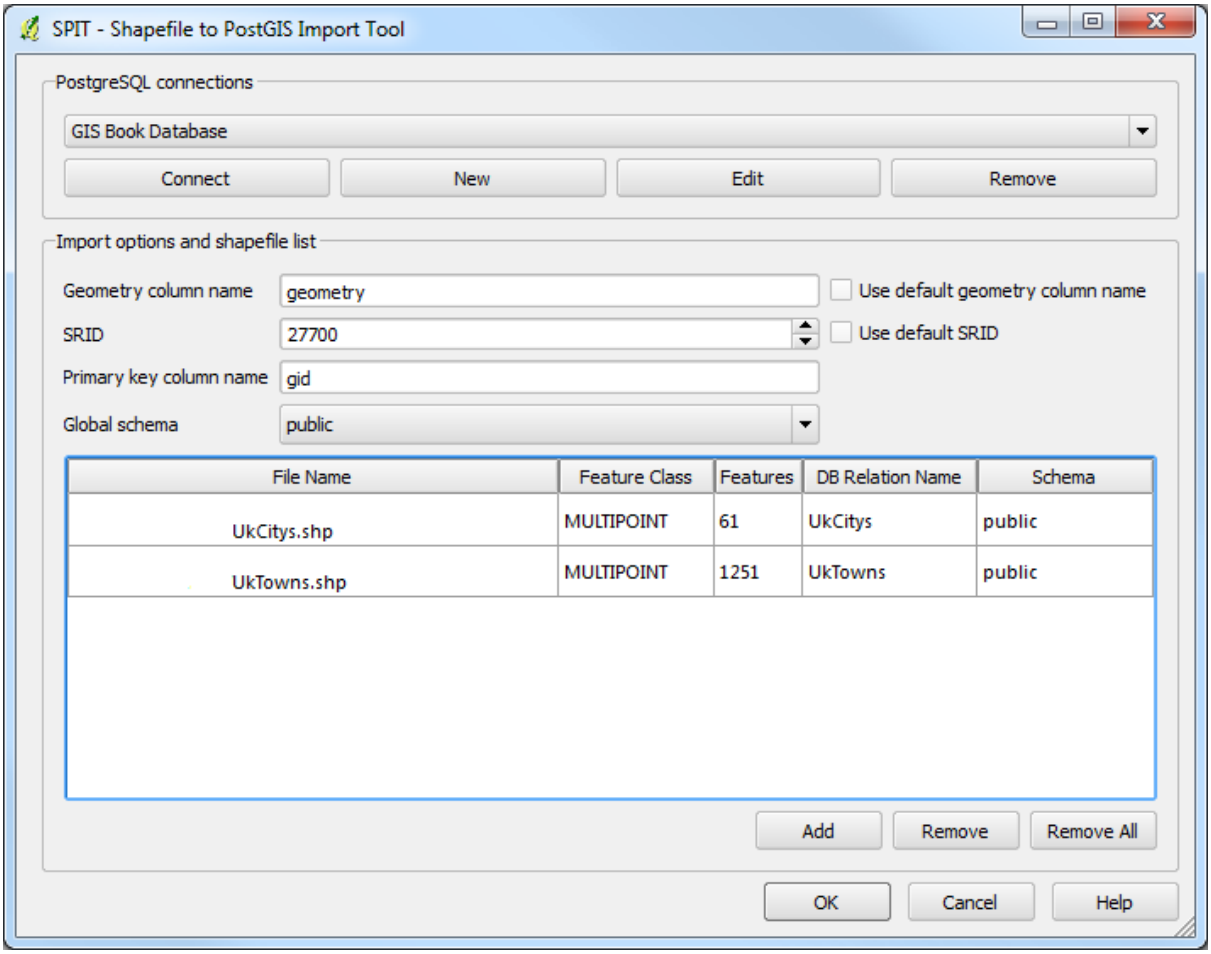


Figure 23: Completed SPIT Dialog

Click **OK** to add your data into your Postgres database and create any tables and other objects needed. If you go back to pgAdmin after adding your data and look at the **geometry_columns** table, you'll see that there are now two entries in it.

Once SPIT has finished, you should be able to go back to the main QGIS window and display a Postgres vector layer. We'll wait to do this for the moment though; next we're going to load the county boundary polygons using GeoKettle.

Loading Boundary Polygons Using GeoKettle

Sometimes you need a little bit more control over your data loading process. For instance, you may need to combine two files and make some transformations to your data before importing it into your database.

When you need to go beyond simple loading using SPIT, you need to use an ETL (Extract, Transform, and Load) tool such as GeoKettle. As mentioned previously, GeoKettle is a specialized ETL package that understands geospatial data and all its special metadata.

As with Postgres and QGIS, I'm not going to cover the installation process. It's fairly straightforward if you download the Java installer version. Since it requires Java to run, make sure you have an up-to-date Java VM installed on your computer.

After installing GeoKettle, open the program. You should be presented with something that looks like the following screenshot:

Figure 24: GeoKettle Home Screen

The concepts behind using GeoKettle are slightly different than the normal point-and-click methodology you may be familiar with, but once you get used to them working with GeoKettle is very easy.

Transformations and Jobs

If you click on the **File** menu and select **New**, you'll see that you have two options: **Transformation** and **Job**. The idea here is that many transformations make up a job, allowing you to break your task down into smaller chunks and then reassemble them using a sequence.

If you've ever done any workflow programming in .NET, you'll be familiar with the idea of separate work units and sequencing those pieces to perform a whole task. Using GeoKettle is the same idea. For what we are going to achieve here, we only need a simple transformation, so select the **Transformation** item under **New**.

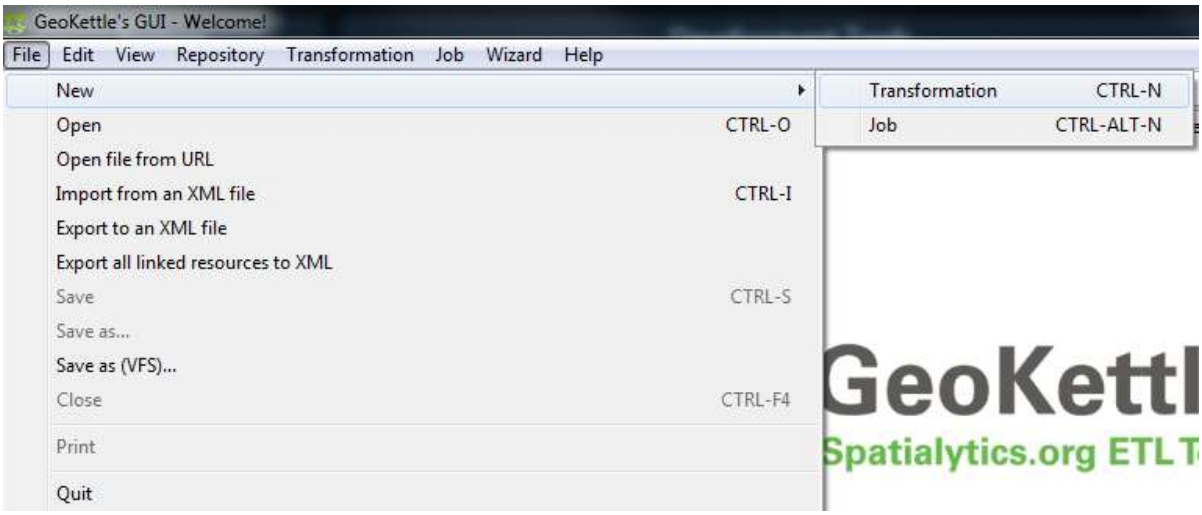


Figure 25: GeoKettle File Menu

Adding Transformation Steps

Once you have a new GeoKettle work surface, you'll notice the designer palette in the left of your screen.

To construct a transformation, drag the necessary steps from this palette to your work surface, and then connect them together by holding **Shift** and dragging between them.

Data then flows from step to step in the direction of your connections, performing the required step as it passes through.

In order to add a shapefile to a database, we need three transformation steps:

1. A shapefile input.
2. A set SRID transform.
3. A table output.

Let's start by adding our input step. Select the **Input** folder in the design palette, and then drag a **Shapefile File Input** onto the work surface as shown in the following screenshot:

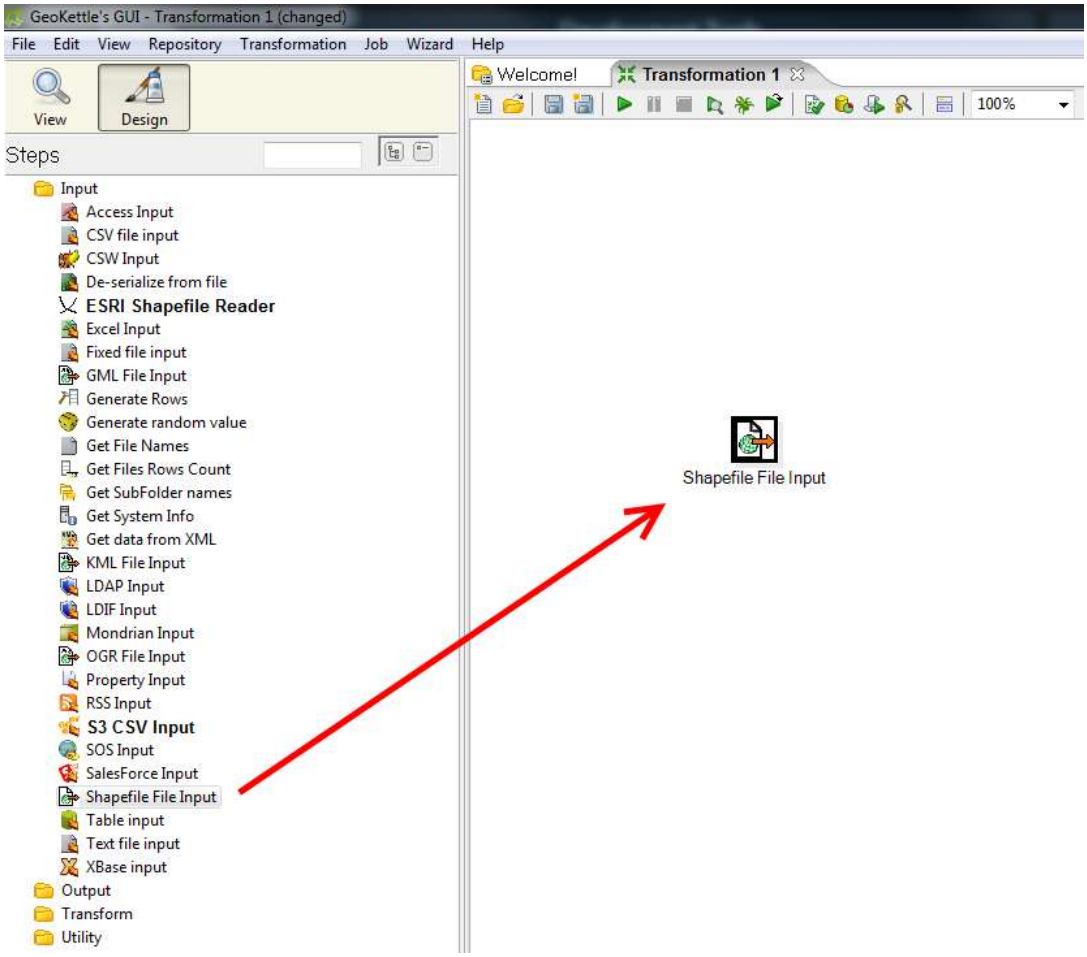


Figure 26: Adding a Shapefile Input Step to the Transformation

Open the **Output** folder in the designer palette and add **Table output** to the transformation.

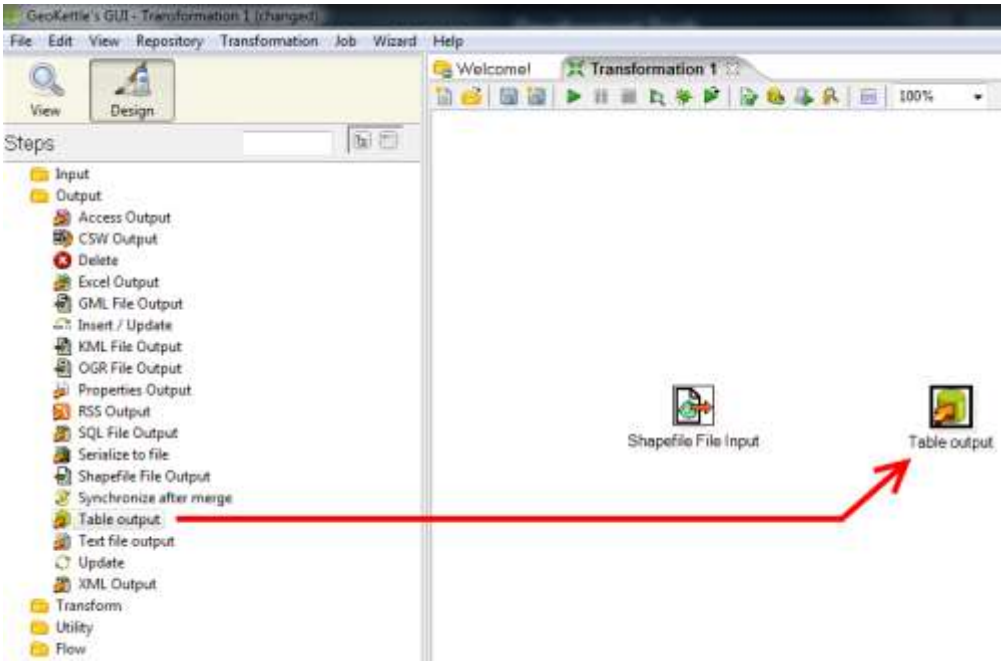


Figure 27: Adding a Table Output Step to the Transformation

Open the **Transform** folder in the designer palette and add the **Set SRS** step.

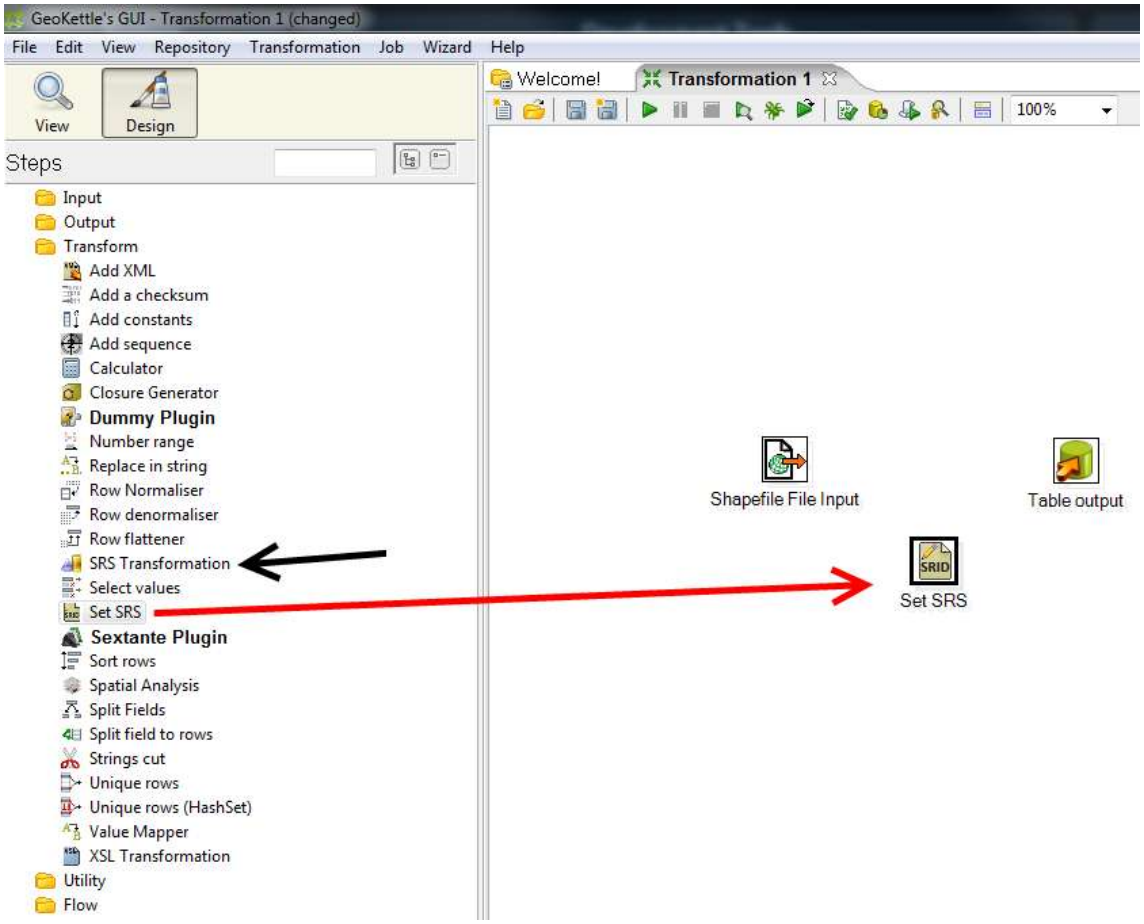


Figure 28: Adding a Set SRS Step to the Transformation

Note the black arrow in Figure 28 pointing at **SRS Transformation**—be careful not to use this one as it is an actual data transformation. You may find that you need this if you're transforming your data from one spatial system to another; for example, if you have a GPS course recorded from a GPS device, it may be in WGS84 coordinate space, but you may need to change it to a local UTM system that matches your area of the globe.

Set SRS does NOT transform the actual coordinate values; it simply sets the SRID of the data you're adding. You must ensure that this SRID is the correct value; otherwise, when you try to demonstrate or project your data, your geometry will appear in a completely different place than where you expect it.

Once you've added the necessary steps to the workspace, you need to connect them. To do this, click on one of your steps to select it, hold **Shift**, and then click and drag to the step you wish to connect. One thing that may be confusing is that GeoKettle does not draw a line as you drag the pointer from one step to the next. Just keep moving the pointer to your next transformation step and release the mouse button when you reach it.

For our example, connect the **Shapefile File Input** to **Set SRS**, and then connect **Set SRS** to **Table output**. If all goes as expected, you should see something like the following:

Figure 29: Connected Transformation Steps

Configuring the Steps

Once you have everything connected, you should be ready to configure everything. We'll start by configuring the shapefile input. Double-click the **Shapefile File Input** step to gain access to its properties.

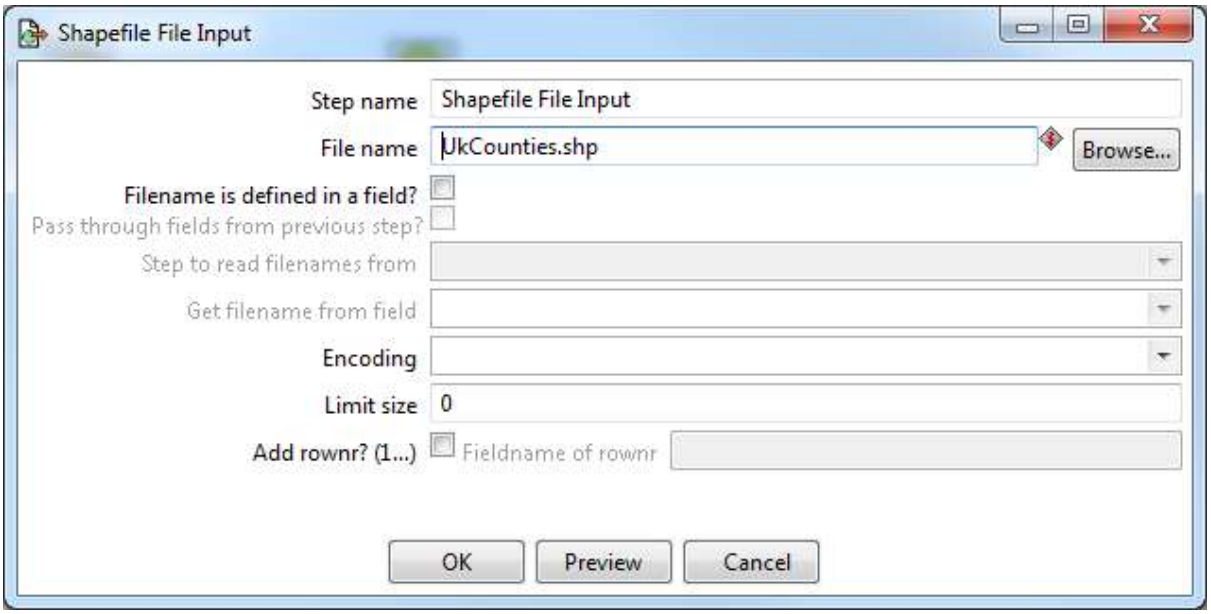


Figure 30: Configuring the Shapefile Input

The only thing we need to change is the file name. Click the **Browse** button, browse to the location of the sample shapefile for the U.K. county boundaries you downloaded, and click **OK**.

You can use the **Preview** button to take a quick peek at your file before you click **OK**. After clicking **Preview**, you'll be prompted for how many rows you want to preview.

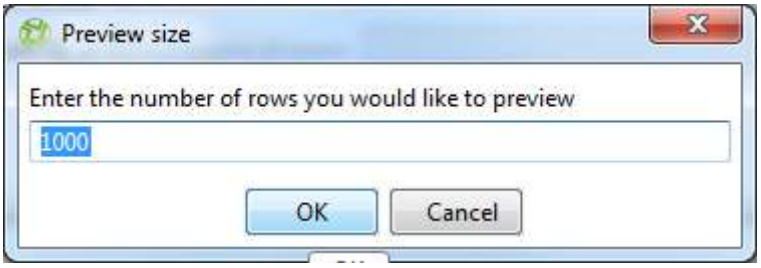


Figure 31: Previewing the Shapefile Input

Entering **0** will show all the rows in the input file. Click **OK** to display the preview. GeoKettle will open the file and show you a spreadsheet-like view of the data and any attributes within the file.

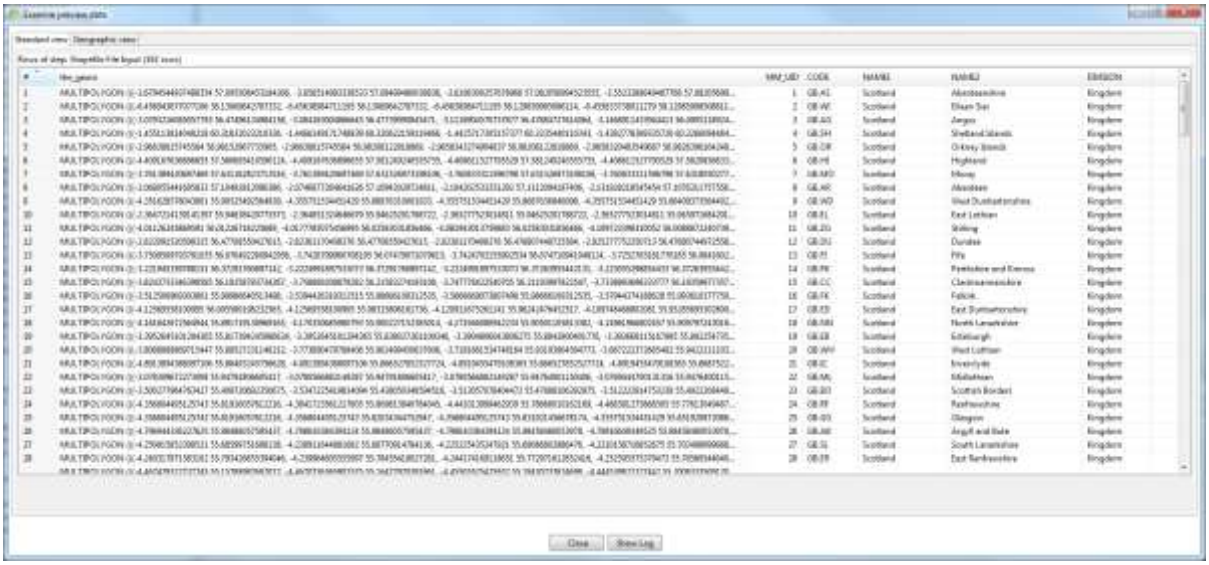


Figure 32: Shapefile Data Preview—Standard View

You can click the **Geographic view** tab at the top to see the following:

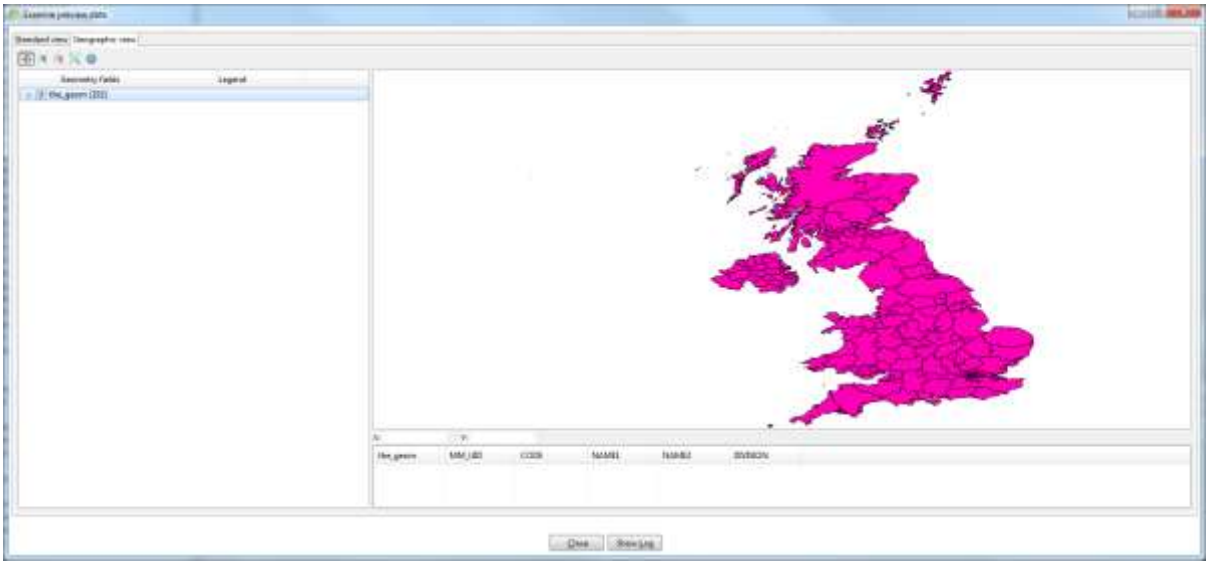


Figure 33: Shapefile Data Preview—Geographic View

When you're finished previewing the data, click **Close**. Click **OK** in the **Shapefile File Input** dialog to complete the shapefile input setup.

The next thing we need to do is set our SRS options. In our case, as you may have noticed when previewing the data, our county boundaries shapefile is actually in WGS84 (SRID 4326) coordinate space. As mentioned previously, we are not going to actually transform the coordinates for this sample data, but in a production system it's highly recommended that you match all your data in the same coordinate space. If I was doing this for a production

system, I'd use the SRS Transformation step and actually change the coordinates to OSGB36 (SRID 27700). For this example, I'm keeping things as simple as possible.

If you want to try transforming your data, note that you'll need two **Set SRS** steps, one on each side of the **SRS Transform** step, to ensure you have the correct spatial ID going into and coming out of the transformation.

Moving on in our example, let's set the singular SRID we need for this data. Double-click the **Set SRS** step to open its dialog; you should see the following:

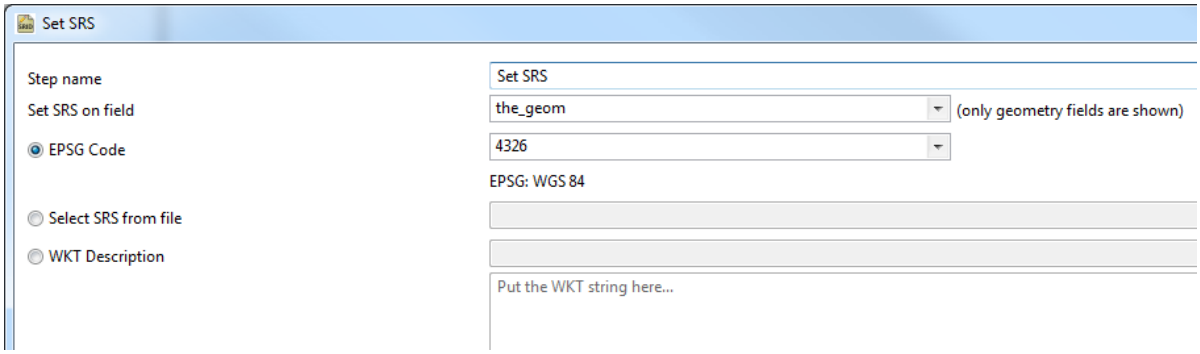


Figure 34: Configuring the Set SRS Step

For the **Set SRS on field** drop-down, select the correct field to set the geometry on. Usually it is called **the_geom** in a shapefile. In the **EPSG Code** field, select the correct spatial ID for the data. In our case, it will be SRID 4326 (WGS84). You can look through the drop-down list to get an idea of how many SRID coordinate spaces there are. Rather than looking through the entire drop-down list, you can simply type **4326**.

Once you've set the SRID, click **OK** to confirm the SRS settings.

The final step is to set our **Table output** and associated database connection. Double-click the **Table output** step to open its configuration dialog as shown in the figure that follows. Note that I've already filled in the connection and target table details.

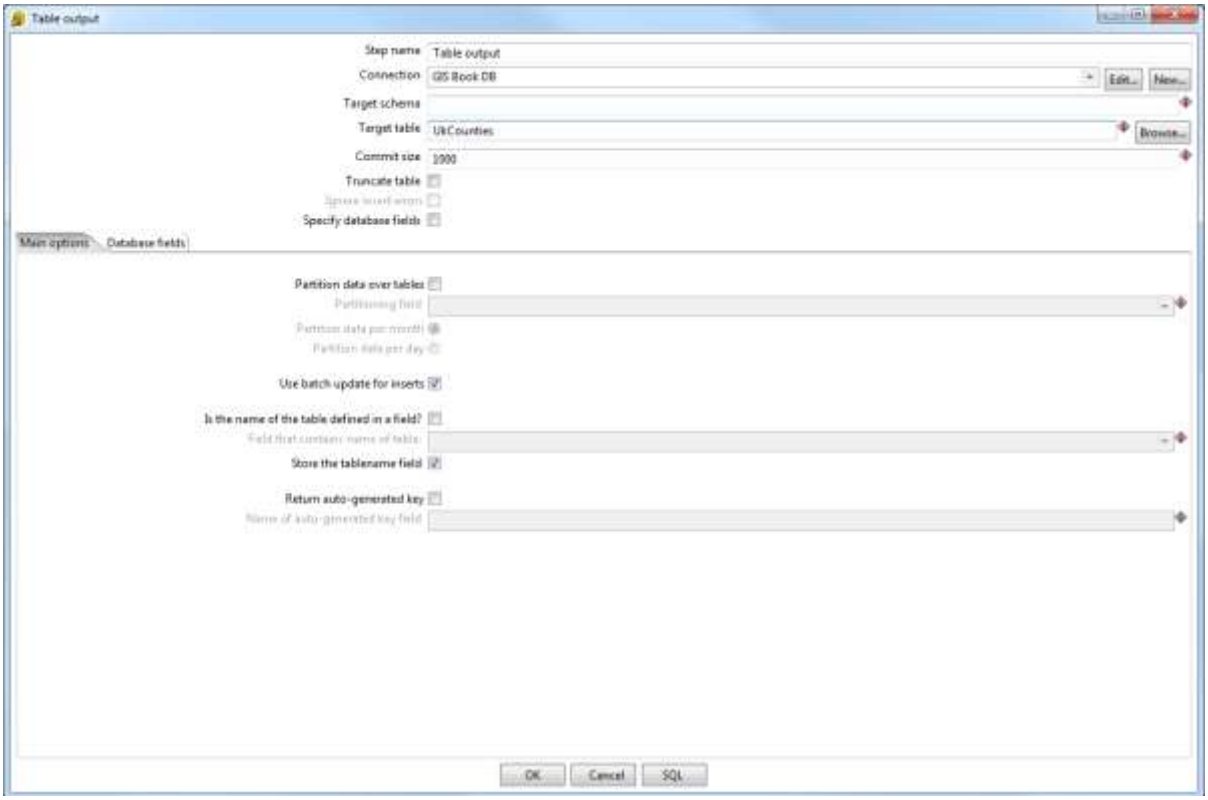


Figure 35: Table Output Configuration

The first thing you'll want to do is create a new database connection. Click the **New** button next to the **Connection** field. The **Database Connection** dialog will appear.

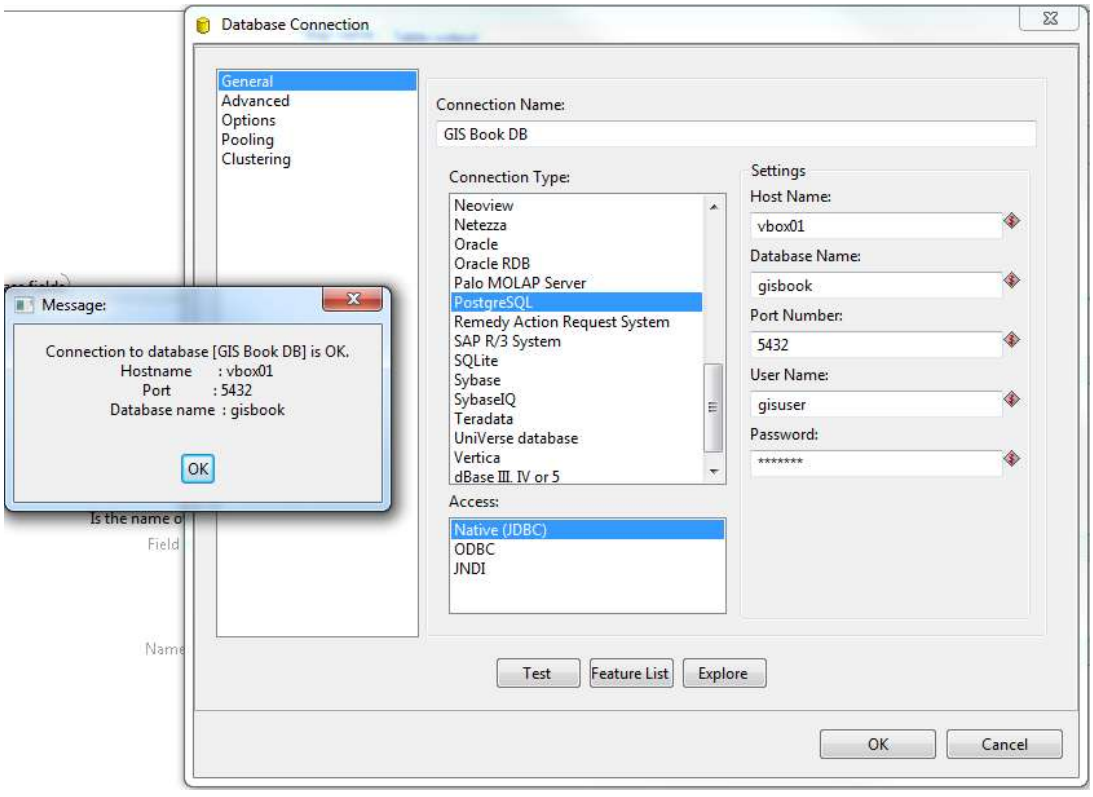


Figure 36: Adding a New Database Connection

Again for Figure 36, I've already filled in my details, but you should easily be able to see that GeoKettle supports a wide variety of database types.

Under **Connection Type**, select **PostgreSQL**. Under **Access**, select **Native JDBC** and fill in the appropriate details to connect to the same database you connected to when adding the point data using QGIS.

Once you're done, give the connection a name and click the **Test** button. You should be shown a small dialog stating that the connection to the database is OK, as shown in the previous figure. Click **OK** to close the dialog, and click **OK** in the **Database Connection** window to go back to the **Table Output** options.

Next, you must set a target table name so the transformation step knows where to insert the data. You may also want to select the **Truncate table** check box to ensure the table is void of data before starting. The other table output settings can usually be left as they are.

If you're creating the data for the first time, you'll need to click the **SQL** button at the bottom of the window to automatically generate and run the SQL necessary to create the initial table in your database. If you're using an existing table, this will give you the SQL needed to ensure the table schema matches the data. It's fairly straightforward, and if you have any knowledge of SQL you'll see immediately what's happening.

One thing I often do in the SQL dialog is add a primary key because GeoKettle does not automatically add one. There are transformation steps for adding primary keys and such, but I find it easier to add the extra field in the SQL editor when creating the table by manually typing in the extra line. In the following figure, you can see I added a primary key with the definition for GID in Postgres.

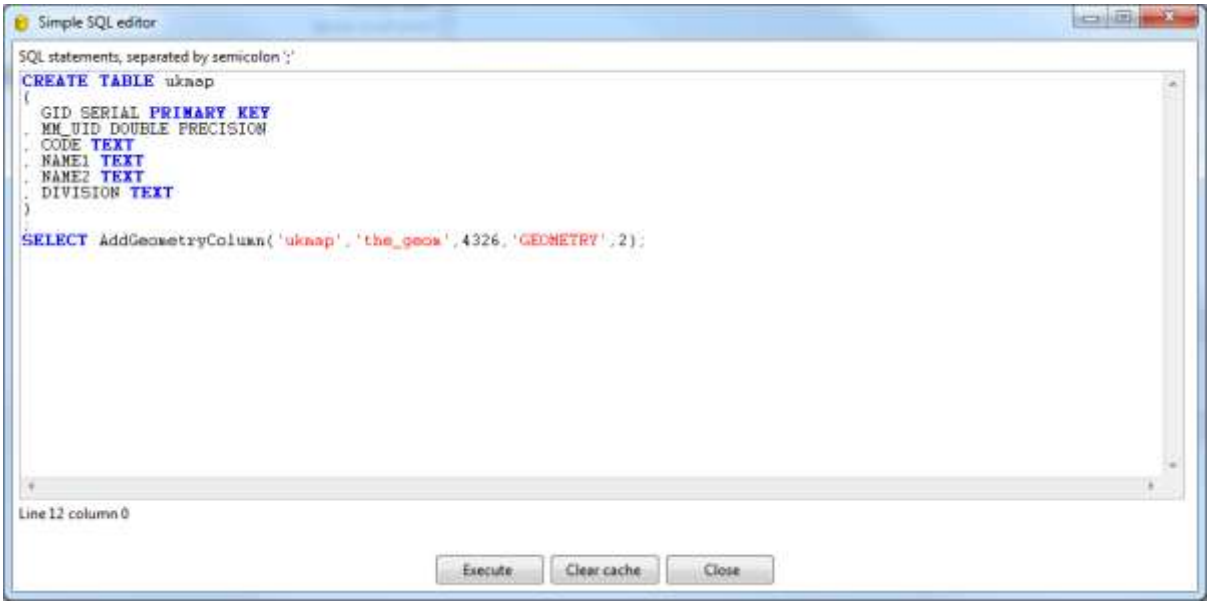


Figure 37: Adding a Primary Key

When you're done editing your SQL, click **Execute** to run it. Once you've run your SQL successfully, you can click **Close** to exit the SQL editor and then click **OK** to navigate back to the transformation workspace. You've completed setting up the required steps.

When you arrive at this point, go to **File** > **Save** to save your loading script. GeoKettle will refuse to run the transformation unless your file is saved. When your script is saved and you're ready to run the transformation, click the green play arrow in the toolbar.

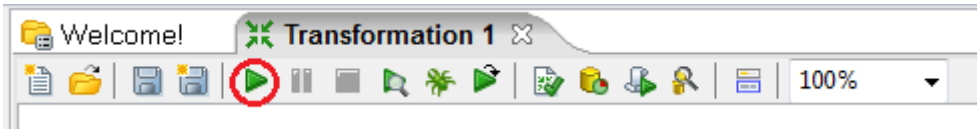


Figure 38: Button to Run Transformation

The **Execute a transformation** window will appear.

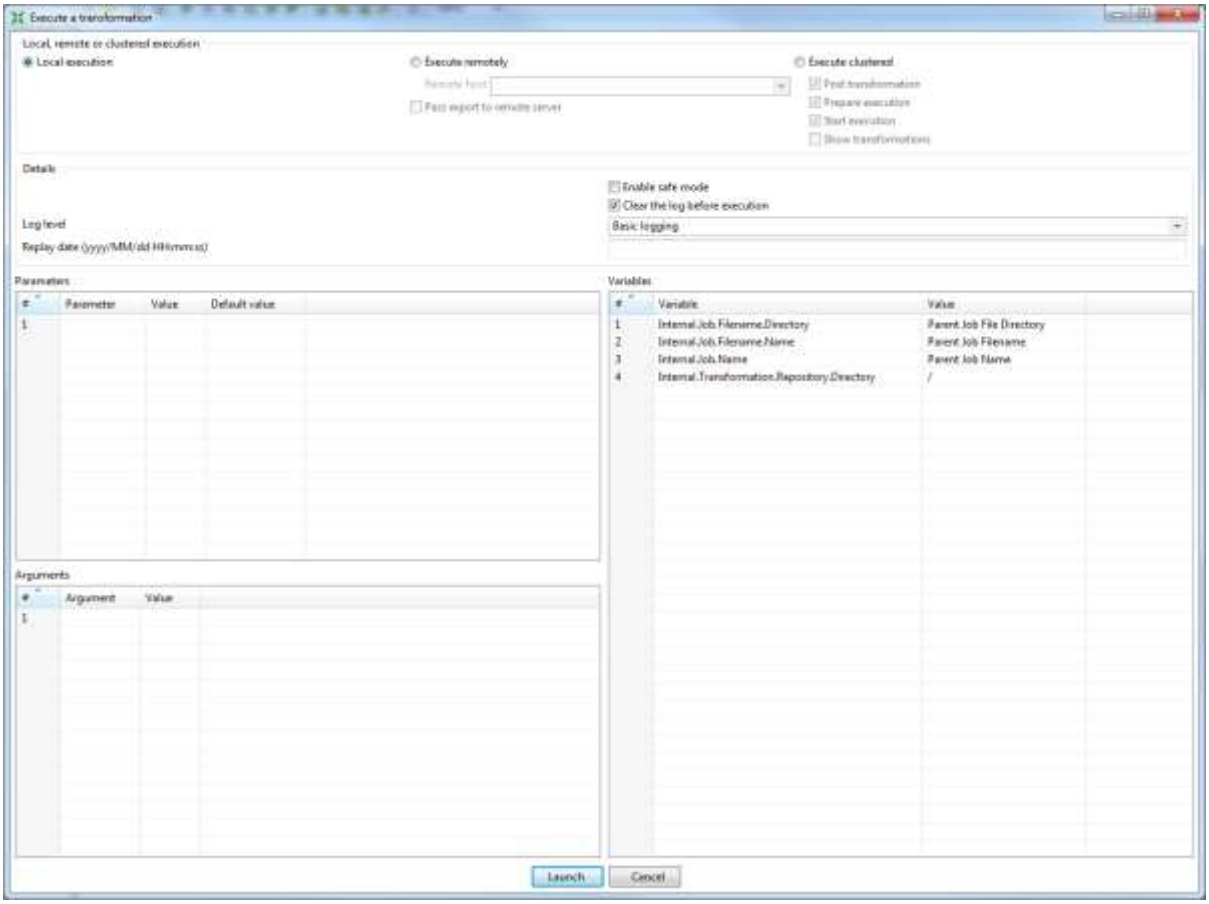


Figure 39: Execute a Transformation Window

99 percent of the time you won't need to change anything in this window. Click the **Launch** button and the lower pane in your workspace will display the transformation progress.

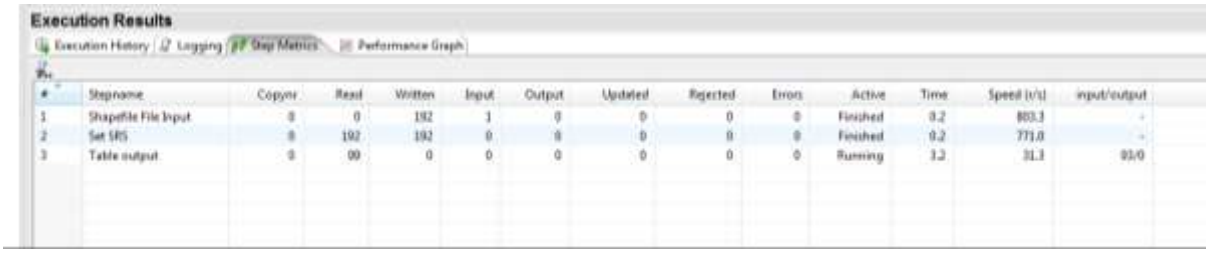


Figure 40: Viewing the Transformation Results

When all your **Active** column entries switch to **Finished**, you should have a database loaded with the county polygons; you are now ready to start experimenting.

If any of the steps turn red and display **Stopped**, you have a problem. The details and stack trace of the problem will be shown in the **Logging** and **Execution History** tabs. Unfortunately, as much as I'd like to be able to list every possible issue you'll see here, I simply can't. When GeoKettle fails, it only releases a stack trace and refuses to do anything further. This probably isn't an issue for the average developer, but for a non-technical user it can look very scary indeed.

My experience with transformation problems is that they're usually some kind of data format issue; for instance, an incorrect setting in the transform step of the destination server spitting out its default data because it doesn't like something about the SQL GeoKettle has just sent to it.

Whenever I receive a stop condition, I copy and paste the output from the **Logging** pane into a text editor so I can start examining SQL statements and diagnosing the stack trace in an easier-to-read window.

Once all of the transformation steps finish successfully, you can close GeoKettle and return to Quantum GIS. Using the connection you created when loading data with SPIT, you can view the data you now have in your database.

Previewing the Data

If we open Quantum GIS and start a new project, the first thing we need to do is set the project properties. We do this by navigating to **Settings** > **Project Properties** in the toolbar.

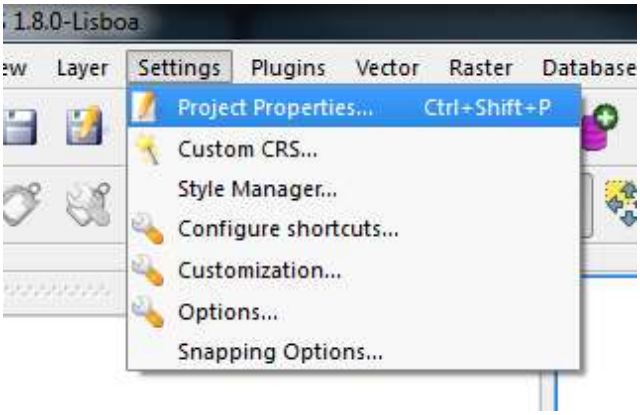


Figure 41: Opening Project Properties in Quantum GIS

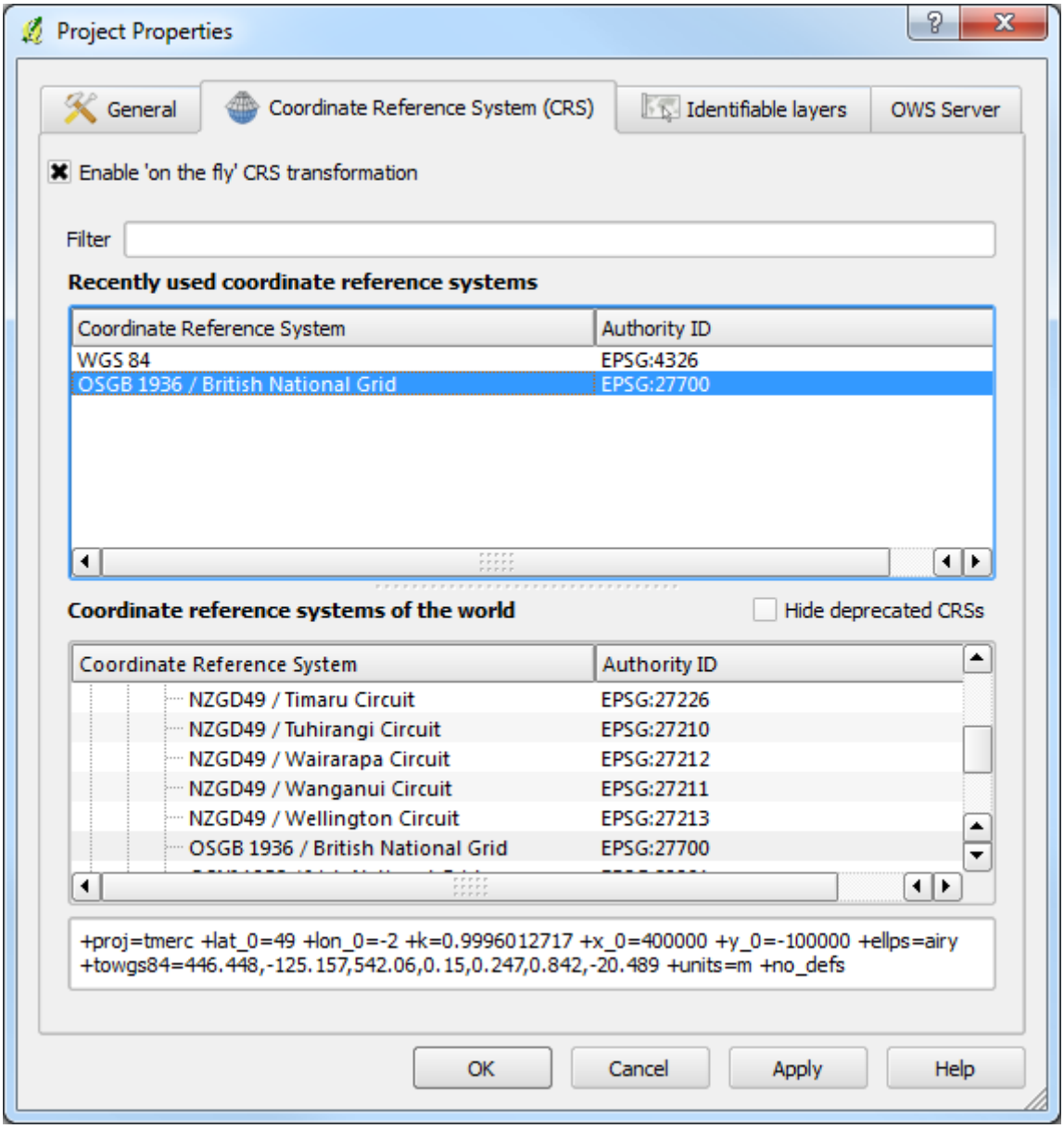


Figure 42: Quantum GIS Project Properties

In **Project Properties**, select the **Enable 'on the fly' CRS transformation** check box since we have both SRID 27700 and SRID 4326 coordinate systems in our database. As you can see in Figure 42, I've selected OSGB36 (SRID 27700) for my project since I reside in the U.K. You can choose WGS84 for your project if you want. As mentioned previously, it's a good practice to select a coordinate system specific to your location.

Once you've selected your coordinate system, click **OK** to return to the main Quantum GIS workspace.

Now we need to start adding vector layers from our database. Click the blue **Add Database Layer** icon on your toolbar. You'll be presented with the **Add layers** dialog, and should immediately recognize the **Connections** drop-down at the top of the dialog; it looks just like the one you used in SPIT.

Figure 43: Add Database Layer Icon

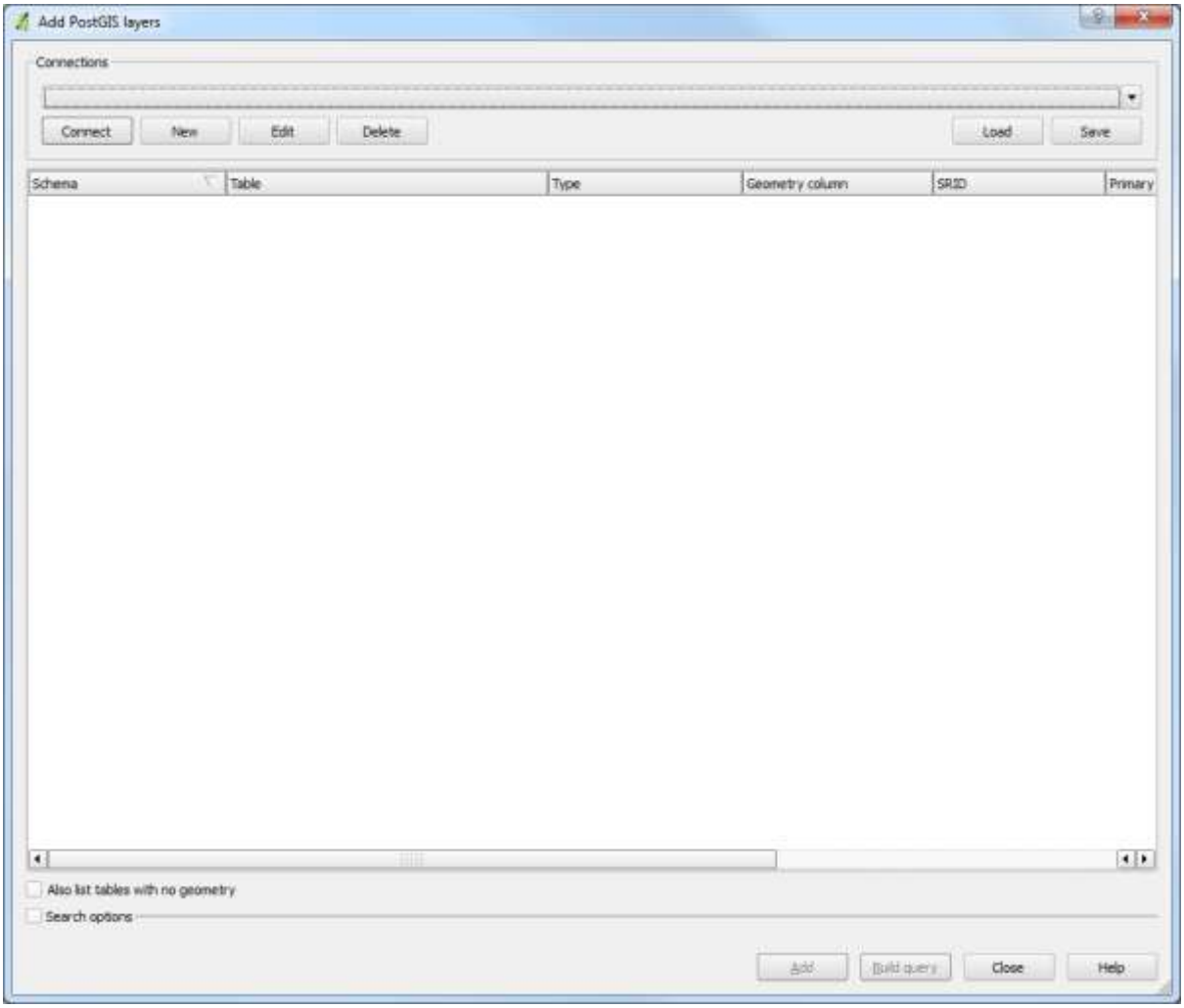


Figure 44: Adding Database Layers

Select the connection you wish to use from the drop-down, or create a new one as you did in SPIT, and click **Connect**. A list of vector layers present in your Postgres database should appear as shown in the following figure:

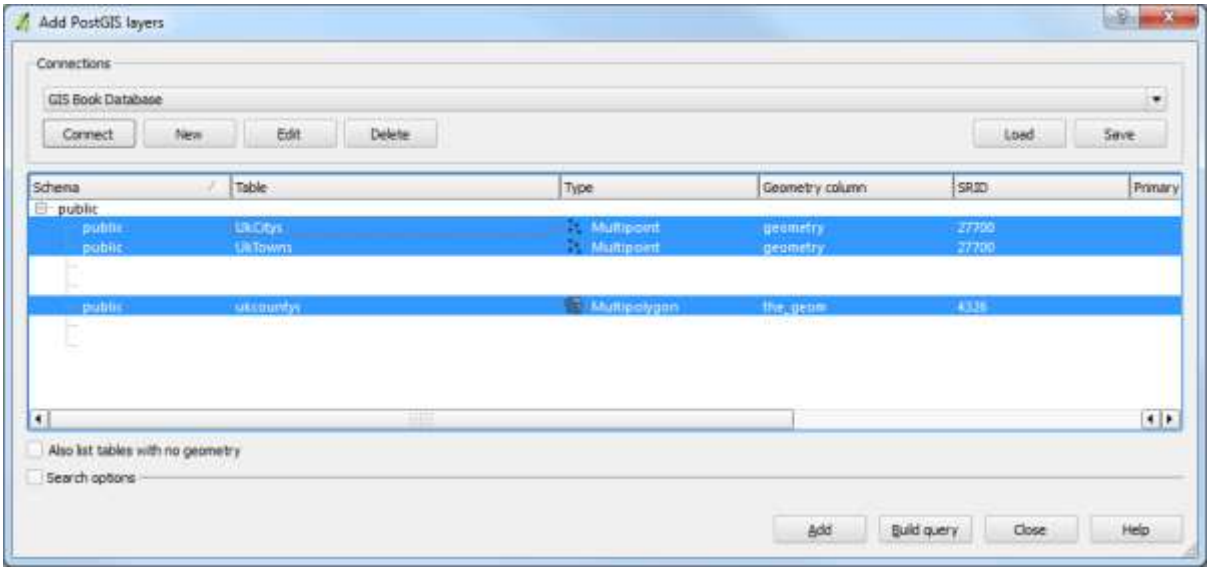


Figure 45: Available Vector Layers

As you can see, the two point layers we imported earlier and the polygon layer we imported using GeoKettle are available. Select all of them and click **Add**.

After a bit of processing, depending on your computer and database speed, QGIS should display the layers, hopefully in three different styles.

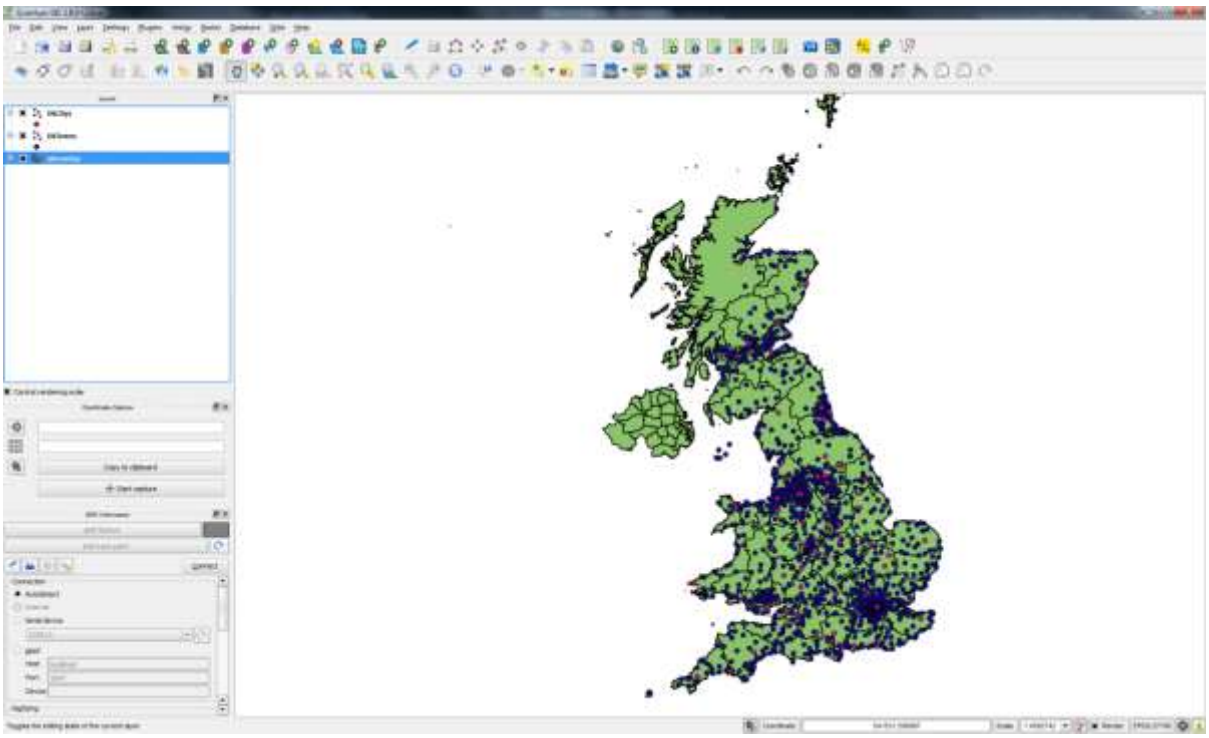


Figure 46: Loaded Map with Three Layers

As shown in my example in Figure 46, county boundaries are in green, towns are dark blue, and cities are pink.

If your display looks anything like mine, then congratulations, you've just created your very first spatially enabled database. Now we get to play with this data.

Chapter 4 Spatial SQL

I've mentioned this breed of SQL many times in this book, and to some extent I've also described it in a brief fashion.

Spatial SQL is not anything special; if you take "Spatial" out of the name, it's just regular SQL. Either way you're dealing with binary large objects, or blobs.

Just like working with images embedded in the database, these blobs have a special meaning when processed by code that understands what they contain. It's the addition of this code along with the extra SQL functions needed to use it that makes a spatially enabled database.

In the following section, I'm not going to cover every possible permutation and function call. At last count there are more than 300 independent functions in the OGC specification, covering just about every possible scenario from spatial distance relationships, to constructions of complex geometries, to clipping rasters for predefined vector paths.

Instead, using the data we've placed in our database, I'll guide you through some simple but common operations—the type that anyone writing a GIS-enabled application is likely to use.

Before we discuss these operations, let's take a quick look at the input and output stages described in the first chapter.

Creating and Retrieving Geometry

Even though we've already imported some data into our database, anyone writing a GIS app also needs to be able to create geometry in the database, especially if the application is going to allow editing.

Most geometry creation is performed in one of three formats:

- Well-known text (WKT)
- Extended well-known text (EWKT)
- Well-known binary (WKB)

We'll be using WKT in the examples that follow, and we'll only be performing the operations in SQL without inserting any data into our database. EWKT is slightly different, mostly due to the fact that in the textual representation of the geometry, the SRID is separated from the rest of the data by a semicolon.

I prefer to use the WKT standard and the spatial function **`ST_SetSrid`** to set the SRID for my geometries.

If you are using MS SQL, you may have to use EWKT since it doesn't have a **`ST_SetSrid`** function. There is, however, a writable **`SRID`** property on the **`Geometry`** SQL type.

So how do we create a geometry using WKT? Try the following SQL:

```
SELECT ST_GeomFromText('LINESTRING(1 1,2 2,3 3,4 4)')
```

This creates a four-segment linestring that starts at 1,1, ends at 4,4, and passes through 2,2 and 3,3. The following is another example of creating geometry with SQL:

```
SELECT ST_GeomFromText('POINT(5 6)')
```

This creates a point at 5, 6 in the current coordinate system.

You can include an optional second parameter that specifies the SRID of the geometry. So if we wanted to create our point in OSGB36 (SRID 27700) coordinates, we'd use the following:

```
SELECT ST_GeomFromText('POINT(5 6)',27700)
```

If you try this using the SQL editor in pgAdmin, you'll find that the database doesn't complain about the coordinates not being valid for the coordinate system being used. That's because the second parameter only sets the field in the geometry blob to say what the geometry's coordinate system is; it does not set anything in the metadata tables or anywhere else in the system to mark that SRID.

Please also note that if you are trying to insert these geometries into a table you have created, the triggers and constraints on those tables will have been set by the table creation functions to allow only certain geometry types and SRIDs to be inserted. This can disrupt many new GIS developers. If the second parameter is not specified, the database will set it to the table default. It's all too easy to insert an invalid coordinate if you don't specify the SRID.

If you do specify the SRID, but it doesn't match the SRID of the table you are inserting the geometry into, then the insert will be rejected and not committed to the table. It is very important to be sure when creating new geometries by hand that you have the correct SRID for your data, and that it matches the constraints of any tables you may have created.

Any of the geometry types we discussed in Chapter 1 can be used in the **`GeomFromText`** function, but beware as sometimes things are not quite as simple as you may expect, especially when it comes to MULT geometries.

The following is a simple point type.

```
SELECT ST_GeomFromText('POINT(5 6)')
```

Multipoints, on the other hand, look like this:

```
SELECT ST_GeomFromText('POINT((5 6)(6 7))')
```

As you can see, simple parenthesis nesting can quickly become a nightmare. Some of the most bizarre bugs I've had to track down in GIS were a direct result of a missing parenthesis.

The same format is used for all other geometry types too.

```
SELECT ST_GeomFromText('MULTILINE((1 1,2 2)(1 2,2 1))')
SELECT ST_GeomFromText('MULTILINESTRING((1 1,2 2,3 3,4 4)(5 5,6 6,7 7,8 8))')
```

The exception to the rule is polygons. Because polygons can include inner rings, a standard polygon actually looks like a single multipolygon from the start. This means that multipolygons have three sets of parentheses surrounding them.

```
SELECT ST_GeomFromText('POLYGON((x y,x y,x y,x y..)(x y,x y,x y,x y..))
SELECT ST_GeomFromText('MULTIPOLYGON(((x y,x y,x y,x y..) (x y,x y,x y,x y..))((x
y,x y,x y,x y..) (x y,x y,x y,x y..)))')
```

This is not very nice to debug. Using a library like DotSpatial or SharpMap helps tremendously because it has functionality built in that allows you to use a familiar C# or VB object and have this text, or even a direct WKB representation, generated on the fly for you so you won't have to construct these geometries by hand.

There are other input functions besides **`GeomFromText`**. Most of them mirror the equivalent output functions listed in the next section. For your reference, I've listed some of the input functions available in the latest version of Postgres:

```
ST_GeomFromEWKB()
ST_GeomFromEWKT()
ST_GeomFromGML()
ST_GeomFromKML()
```

Other geometry functions available in the latest version of Postgres include:

```
ST_Point()
ST_LineFromMultiPoint()
ST_Polygon()
```

All of which are detailed in the Geometry Constructors section of the online PostGIS manual at http://postgis.refractions.net/docs/reference.html#Geometry_Constructors. Most of the geometry constructors are also defined in the OGC specifications.

Output Functions

Now that we've seen how to generate geometry objects, it would be great to be able to get our data back out of the database.

If you want just the binary blob representation, a simple **`Select`** will do the job. In the creation samples in the previous section, because we weren't inserting the data, the output was the actual binary blob that represented the geometry.

One thing you must be cautious of: when dumping the blob directly, it might *not* be a WKB formatted object. Some database services store the data in an internal format which allows them to manage it quicker and easier than if it were WKB. If you want to ensure you always receive a WKB output, be sure to use the correct output function as shown in the following code:

```
SELECT ST_AsBinary(geometry)
```

Quite a few textual output functions are available as well, such as:

```
SELECT ST_AsText(geometry)
```

This will output your geometry in the WKT format.

If you want your geometry output in the EWKT format, use the following:

```
SELECT ST_AsEWKT(geometry)
```

If you're displaying your geometry in an HTML 5 page using SVG, then you'll use the following:

```
SELECT ST_AsSVG(geometry)
```

This returns an SVG tag ready to be inserted directly into your output or an SVG file.

If you're creating output for use in Google Earth or any other app that supports Keyhole Markup Language, use the following function:

```
SELECT ST_AsKML(geometry)
```

If you're outputting industry-standard Geography Markup Language (GML) or GeoJSON (A special format of JSON designed especially for geographic data),

```
SELECT ST_AsGML(geometry)
```

and

```
SELECT ST_AsGeoJSON(geometry)
```

will be your functions.

Some servers also provide other output functions on top of that, such as the following Postgres function:

```
SELECT ST_AsLatLonText(geometry)
```

This outputs coordinates in NMEA seconds, minutes, and degrees format, but the use of this is considered non-standard and may make it hard to port your application between database platforms.

Let's have a quick look at one or two of these functions using the cities point data we added to our database. To do this, we'll use the SQL editor in pgAdmin. To open the SQL editor, select the database you wish to work in— in our case the **GISBook** one if you've been following along—and click on the SQL magnifying glass icon on the toolbar.

Figure 47: SQL Editor Icon

This will open the **SQL Editor** pane.

Figure 48: SQL Editor

Type your SQL statements in the top pane, and press **F5** or click the green arrow to run your SQL. The results and messages will appear in the lower pane.

A side note on using SQL in Postgres

Using SQL in Postgres is likely to cause some users problems: Postgres is case sensitive by default. If you create a table or other object with a name with specific casing, it will create exactly that name. However, when trying to access the object, Postgres will look for the object name using all lowercase letters unless the name is enclosed in quotation marks.

As an example, if I **`CREATE TABLE Shawty`**, then the table will be named **`Shawty`** with a capital S. But if I then run **`SELECT * FROM Shawty`**, Postgres will fail to find the table. Instead, I need to type **`SELECT * FROM "Shawty"`** to make Postgres pay attention to the casing of the name.

This also extends to the Postgres data adapter for .NET. If you are unable to access a table in the Postgres data adapter, try putting the table name in quotation marks and you'll most likely find it resolves the issue.

Please note that regular strings are enclosed with single quotes, not double quotes. If you enclose your literal string in double quotes, Postgres will interpret your text as an object name and not as data.

The best practice for creating objects in Postgres is to give them all lowercase names. I've done exactly this for the database I'll be using to demonstrate the SQL functions, and I've changed all the names of tables and columns to lowercase after importing the data as shown previously. I've also removed columns from the dataset that are unused either in the examples, or in general.

If you receive errors while trying the samples, make sure that you're making the same changes I am, using single and double quotes properly, and correctly casing names as needed.

Testing the Output Functions

Let's try the following:

```
SELECT * FROM ukcitys LIMIT 5
```

You should receive something like the following output:

Data Output | Explain | Messages | History

	gid integer	number double precision	name character varying(180)	admin_name character varying(50)	geometry geometry
1	1	2506	WAKEFIELD	WAKEFIELD	0104000020346C0000
2	2	2708	KINGSTON UPON HULL	CITY OF KINGSTON UPON HULL	0104000020346C0000
3	3	2737	PRESTON	LANCASHIRE COUNTY	0104000020346C0000
4	4	2825	BRADFORD	BRADFORD	0104000020346C0000
5	5	2840	LEEDS	LEEDS	0104000020346C0000

Figure 49: Data Output with Binary Geometry

As you can see, the **geometry** column is displayed in its binary form, which may or may not be in WKB format.

Now let's try this:

```
SELECT gid,number,name,admin_name,AsText(geometry) FROM ukcitys LIMIT 5
```

You should receive the following:

Data Output | Explain | Messages | History

	gid integer	number double precision	name character varying(180)	admin_name character varying(50)	astext text
1	1	2506	WAKEFIELD	WAKEFIELD	MULTIPOINT(433150 420810)
2	2	2708	KINGSTON UPON HULL	CITY OF KINGSTON UPON HULL	MULTIPOINT(509290 428350)
3	3	2737	PRESTON	LANCASHIRE COUNTY	MULTIPOINT(355130 429048)
4	4	2825	BRADFORD	BRADFORD	MULTIPOINT(416615 432926)
5	5	2840	LEEDS	LEEDS	MULTIPOINT(430280 433650)

Figure 50: Data Output with Text Geometry

As shown in the previous figure, the output is in WKT format with the coordinates in meters since we're using OSGB36 as the SRID.

Let's swap **`AsText`** for **`AsEWKT`**. We should get the following:

Data Output | Explain | Messages | History

	gid integer	number double precision	name character varying(180)	admin_name character varying(50)	asewkt text
1	1	2506	WAKEFIELD	WAKEFIELD	SRID=27700;MULTIPOINT(433150 420810)
2	2	2708	KINGSTON UPON HULL	CITY OF KINGSTON UPON HULL	SRID=27700;MULTIPOINT(509290 428350)
3	3	2737	PRESTON	LANCASHIRE COUNTY	SRID=27700;MULTIPOINT(355130 429048)
4	4	2825	BRADFORD	BRADFORD	SRID=27700;MULTIPOINT(416615 432926)
5	5	2840	LEEDS	LEEDS	SRID=27700;MULTIPOINT(430280 433650)

Figure 51: Data Output with EWKT Geometry

You may have noticed that in these examples I've been calling the functions without the **ST_** in front. **ST_** is a legacy tag from when systems were called Spatial and Temporal systems. In most modern GIS databases, you can freely switch between using the prefix and leaving it out since most systems define the function both with and without the '**ST**_' prefix. One or two functions are defined only with the **ST_** prefix, so if something seems to be missing in your data, try both spellings before you give up.

As you can see, the main difference between **AsText** and **AsEWKT** is the addition of the SRID in the output.

Let's try one more, this time with the data output in GeoJSON format:

```
SELECT gid,number,name,admin_name,ST_AsGeoJSON(geometry) FROM ukcitys LIMIT 5
```

Data Output | Explain | Messages | History

	gid integer	number double precision	name character varying(180)	admin_name character varying(50)	st_asgeojson text
1	1	2506	WAKEFIELD	WAKEFIELD	{"type":"MultiPoint","coordinates":[[433150,420810]]}
2	2	2708	KINGSTON UPON HULL	CITY OF KINGSTON UPON HULL	{"type":"MultiPoint","coordinates":[[509290,428350]]}
3	3	2737	PRESTON	LANCASHIRE COUNTY	{"type":"MultiPoint","coordinates":[[355130,429048]]}
4	4	2825	BRADFORD	BRADFORD	{"type":"MultiPoint","coordinates":[[416615,432926]]}
5	5	2840	LEEDS	LEEDS	{"type":"MultiPoint","coordinates":[[430280,433650]]}

Figure 52: Data Output with GeoJSON Geometry

What Else Can We Do with Spatial SQL?

We can do tons of things with spatial SQL. A better question is what can't we do? However, as a developer, you're most likely only interested in simple tasks, so we'll continue by looking at a few real-world scenarios and what our database can do to help us.

Scenario 1: Largest land mass

Let's suppose you have a number of land plots for sale, and you have them all in a nice mapping system that potential buyers can browse via a map-enabled website. One thing you may want to know is which plot has the largest area so you can price them appropriately.

This is achieved very simply by using the area functions provided by the database.

```
SELECT name2,ST_Area(the_geom) FROM ukcountys LIMIT 5
```

Data Output | Explain | Messages | History

	name2 character varying(25)	st_area double precision
1	Aberdeenshire	0.93850119170321
2	Eilean Siar	0.490237451719565
3	Angus	0.309781683173085
4	Shetland Islands	0.236804654159947
5	Orkney Islands	0.164896918183942

Figure 53: Calculated Land Areas

You'll notice that all our results are in square degrees or fractions thereof. This is because our geometry was added to the database in WGS84 (SRID 4326) coordinates. Most of the calculation functions will return their answers in the same units that the source geometry uses. Converting our area results to meters is not difficult.

SRID 27700, if you recall, is measured in meters so all we need to do is transform our geometry from SRID 4326 to SRID 27700. We can do this using **`ST_Transform`**.

The transform function takes the geometry to be transformed as the first parameter, and the SRID to transform it to as the second. Using the function on our data gives us the following SQL:

```
SELECT name2,ST_Area(ST_Transform(the_geom,27700)) FROM ukcountys LIMIT 5
```

Data Output | Explain | Messages | History

	name2 character varying(25)	st_area double precision
1	Aberdeenshire	6305704807.73494
2	Eilean Siar	3240437198.02938
3	Angus	2110168969.97424
4	Shetland Islands	1454431846.82245
5	Orkney Islands	1054203070.63693

Figure 54: Geometry Converted from Square Degrees to Meters

Once you have the data converted from square degrees to meters, you can then use normal SQL **`order by`** clauses and other aggregate functions to arrange the areas from largest to smallest, or add a price column. For example, the following code outputs the five largest counties in the U.K. and their areas in square meters.

```
SELECT name2,ST_Area(ST_Transform(the_geom,27700)) FROM ukcountys order by
ST_Area(ST_Transform(the_geom,27700)) desc LIMIT 5
```

Data Output | Explain | Messages | History

	name2 character varying(25)	st_area double precision
1	Highland	26117991850.3414
2	North Yorkshire	7965335521.24405
3	Argyll and Bute	7268953963.16329
4	Cumbria	6851265194.55653
5	Devon	6606581812.45006

Figure 55: Five Largest Counties in the U.K in Descending Order

Another thing that might be useful to know is how long the perimeter of the land mass is. Finding this is just as easy, as shown in the following code sample and data output:

```
SELECT name2,ST_Perimeter(ST_Transform(the_geom,27700)) FROM ukcountys LIMIT 5
```

Data Output | Explain | Messages | History

	name2 character varying(25)	st_perimeter double precision
1	Aberdeenshire	570823.677155048
2	Eilean Siar	2782243.83336142
3	Angus	253455.654047405
4	Shetland Islands	1280077.9778846
5	Orkney Islands	1298534.61420793

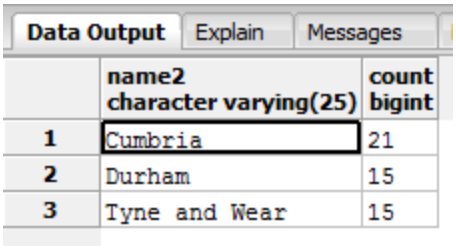
Figure 56: Perimeter of U.K. Counties

Scenario 2: How many of what are where?

Another typical use of GIS is for gathering information on how one object's location is related to another object's location. For example, given three U.K. counties—Durham, Tyne and Wear, and Cumbria—we can easily find out how many principal towns are in each.

```
SELECT ukcountys.name2,count(uktowns.*)
FROM ukcountys,uktowns
WHERE ST_Within(uktowns.geometry,ST_Transform(ukcountys.the_geom,27700)) AND
ukcountys.name2 IN ('Durham','Tyne and Wear','Cumbria')
GROUP BY ukcountys.name2
```

This code gives us the following:



Data Output | Explain | Messages

	name2 character varying(25)	count bigint
1	Cumbria	21
2	Durham	15
3	Tyne and Wear	15

Figure 57: Number of Towns in Cumbria, Durham, and Tyne and Wear Counties

The SQL for this introduces the spatial function **`ST_Within`**, which tests to see if one geometry is fully within another.

There are two important concepts to remember from this example:

- For one object to be within another, the inner object must be fully inside the outer object's bounding line. In the county example, if your geometry is smaller than the thickness of any of the county boundary lines and lies directly on one, **`ST_Within`** would not have picked it up. Instead, it would have been identified as *intersecting* with the geometry rather than being within it.
- The order of parameters on some spatial SQL functions is important. In the county example, if you switch the order of the county and town parameters, you'll find that you receive no results because a point cannot fully contain a polygon that is much larger than itself.

Because spatial SQL accounts for boundary polygons when performing relationship-based measurements, there are a number of different functions that perform very similar tasks with slight differences.

In the case of **`ST_Within`**, we have the following similar functions:

- **`ST_Contains`**
- **`ST_Covers`**
- **`ST_CoveredBy`**
- **`ST_Intersects`**

The Postgres and OGC specifications document the differences in fine detail way better than I can describe here, but essentially one only works on the interior of the polygon, and the others work on combinations of the interior enclosing ring and various levels of intersection.

As a developer, you'll most likely never use anything other than **`ST_Within`**, and in rare cases **`ST_Contains`**, for most of the GIS work you'll do.

In our counties example, you can also see that we've had to use **`ST_Transform`** to transform our counties into the correct SRID again. If you keep all your geometry in the same SRID when loading your database, you begin to see how much simpler your SQL can be.

Scenario 3: How close is this to that?

Knowing how far away something is always has a place in GIS. Whether you need to know how close the nearest McDonald's is, or how close a friend's house is, this is one of the most

common operations used in GIS since mobile phones started pumping locations out of a built-in GPS unit.

Not only can we get a measurement of the distance something is from the user, but a GIS database can also select objects based on distances from the user within bounding boxes and radii.

Let's try an example. Start by finding the distances of all the towns in County Durham from the principal city of Durham.

```
SELECT t.name,round((ST_Distance(c.geometry,t.geometry) / 1609.344)::numeric,1) as
distanceinmiles FROM ukcitys as c
JOIN uktowns t ON c.admin_name = t.admin_name
WHERE c.name = 'DURHAM'
ORDER BY ST_Distance(c.geometry,t.geometry) desc
```

This code gives us the following:

Data Output | Explain | Messages | History

	name character varying(180)	distanceinmiles numeric
1	BARNARD CASTLE	21.3
2	CONSETT	12.5
3	NEWTON AYCLIFFE	11.9
4	SHILDON	11.0
5	TOW LAW	10.2
6	BISHOP AUCKLAND	9.6
7	SEAHAM	9.2
8	CROOK	8.7
9	ANNFIELD PLAIN	8.5
10	PETERLEE	8.4
11	STANLEY	7.9
12	WILLINGTON	7.0
13	SPENNYMOOR	5.8
14	CHESTER-LE-STREET	5.6
15	BRANDON	3.1

Figure 58: Distances of Towns from Durham in County Durham

The SQL we used is quite simple once you break it down. We performed a natural join on the towns and cities—both have exactly the same columns—on the admin name, using the admin name in the principal city as the master one. We filtered the cities so that only **Durham** is selected, and then we used **`ST_Distance(a,b)`** to get the straight line distance from geometry **a** to geometry **b**.

We then divided this distance by 1609.344 (the number of meters in a mile), cast the result back to a numeric (Output from **`ST`** functions are distance specific, e.g., meters, degrees, etc.), and rounded it to one decimal place, before ordering the towns from furthest to closest.

Brandon is the closest to Durham; Barnard Castle is the farthest away.

Now let's take a look at capturing items in a given radius. Again, we'll use Durham city as our center point, and cast a radius of 10 miles around this point. Then we will list any town that falls in that radius, irrespective of its county.

```
SELECT t.name,t.admin_name,round((ST_Distance(c.geometry,t.geometry) /
1609.344)::numeric, 1) as distanceinmiles
FROM ukcitys AS c, uktowns as t
WHERE c.name = 'DURHAM' AND ST_Distance(c.geometry,t.geometry) <= 16093.44
```

Data Output | Explain | Messages | History

	name character varying(180)	admin_name character varying(50)	distanceinmiles numeric
1	BISHOP AUCKLAND	COUNTY DURHAM	9.6
2	SPENNYMOOR	COUNTY DURHAM	5.8
3	WILLINGTON	COUNTY DURHAM	7.0
4	CROOK	COUNTY DURHAM	8.7
5	BRANDON	COUNTY DURHAM	3.1
6	PETERLEE	COUNTY DURHAM	8.4
7	HETTON-LE-HOLE	SUNDERLAND	5.3
8	HOUGHTON-LE-SPRING	SUNDERLAND	5.6
9	SEAHAM	COUNTY DURHAM	9.2
10	ANNFIELD PLAIN	COUNTY DURHAM	8.5
11	CHESTER-LE-STREET	COUNTY DURHAM	5.6
12	STANLEY	COUNTY DURHAM	7.9
13	BIRTLEY	GATESHEAD	8.3
14	WASHINGTON	SUNDERLAND	9.0

Figure 59: Towns within 10 Miles of Durham

There are 14 towns within 10 miles of Durham city, and as you can see not all of them are in County Durham.

You can also rewrite the SQL with the **`ST_Dwithin(a,b,distance)`** function as follows:

```
SELECT t.name,t.admin_name,round((ST_Distance(c.geometry,t.geometry) /
1609.344)::numeric, 1) as distanceinmiles
FROM ukcitys AS c, uktowns as t
WHERE c.name = 'DURHAM' AND ST_Dwithin(c.geometry,t.geometry, 16093.44)
```

The only thing different is the **<=** clause in the last part of the **WHERE** statement, so what changes? Not much, really. However, if you're using bounding boxes and buffers, you'll often get better results using **ST_Distance** with a **<=** operator.

Again, we used the cast operator to make sure our data output a normal numeric type and rounded it to one decimal place, divided it by 1609.344 to convert it to miles, and finally filtered things so that only towns around Durham were included.

It's easy enough to exchange the Durham city geometry for a GPS point from a GPS device, for example, and list the towns around that point.

```
SELECT t.name,t.admin_name,round((ST_Distance(ST_Point(428110 542709),t.geometry)
/ 1609.344)::numeric, 1) as distanceinmiles

FROM ukcitys AS c, uktowns as t

WHERE c.name = 'DURHAM' AND ST_Dwithin(ST_Point(428110 542709),t.geometry,
16093.44)
```

Or if your GPS is WGS84 (SRID 4326), you'll need to transform it to meters and OSGB36 (SRID 27700).

```
SELECT t.name,t.admin_name,round((ST_Distance(ST_Transform(ST_Point(-1.56450
54.77851),27700),t.geometry) / 1609.344)::numeric, 1) as distanceinmiles

FROM ukcitys AS c, uktowns as t

WHERE c.name = 'DURHAM' AND ST_Dwithin(ST_Transform(ST_Point(-1.56450
54.77851),27700),t.geometry, 16093.44)
```

Scenario 4: What is my geometry made of?

In some cases you may need to take your geometry apart and reassemble it in a different way, or make a new geometry based on the original one.

First off, let's find out how many points make up the border around County Durham.

```
SELECT name2,ST_NPoints(the_geom) FROM ukcountys WHERE name2 = 'Durham'
```

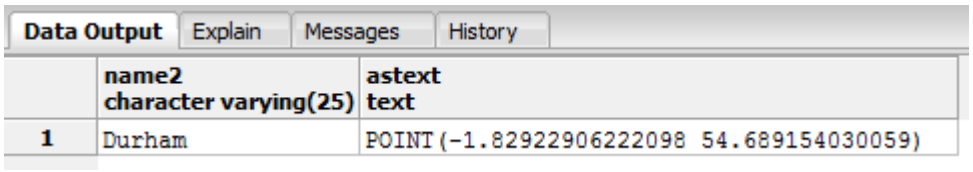
Data Output | Explain | Messages | Histo

	name2 character varying(25)	st_npoints integer
1	Durham	568

Figure 60: Number of Border Points

Or we can find the geographic center point of the county in the same coordinates as the actual geometry.

```
SELECT name2,AsText(ST_Centroid(the_geom)) FROM ukcountys WHERE name2 = 'Durham'
```



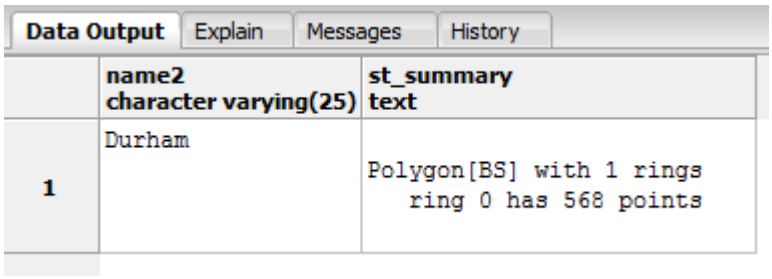
Data Output | Explain | Messages | History

	name2 character varying(25)	astext text
1	Durham	POINT(-1.82922906222098 54.689154030059)

Figure 61: Geographic Center of County Durham

Or we can output a summary of what the object is.

```
SELECT name2,ST_Summary(the_geom) FROM ukcountys WHERE name2 = 'Durham'
```



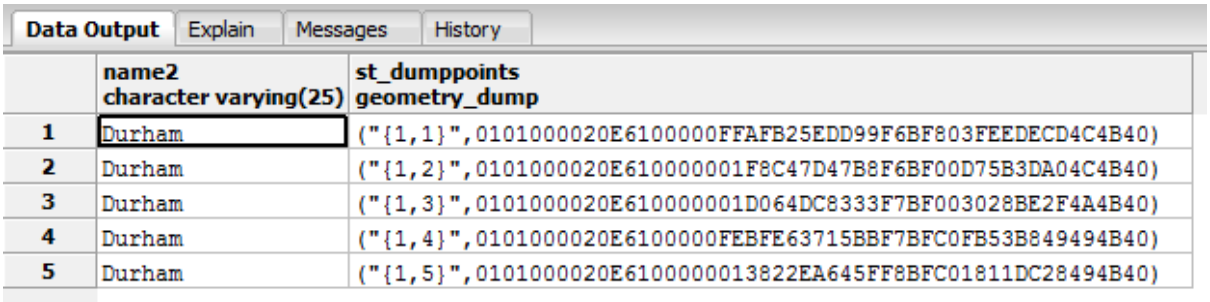
Data Output | Explain | Messages | History

	name2 character varying(25)	st_summary text
1	Durham	Polygon[BS] with 1 rings ring 0 has 568 points

Figure 62: Summary of County Durham Object

We can also break down the underlying geometry. There are functions to dump entire sets of points that make up a boundary.

```
SELECT name2,ST_DumpPoints(the_geom) FROM ukcountys WHERE name2 = 'Durham' LIMIT 5
```



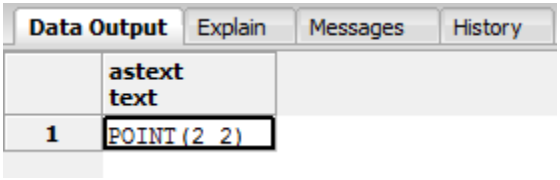
Data Output | Explain | Messages | History

	name2 character varying(25)	st_dumppoints geometry_dump
1	Durham	("{1,1}",0101000020E6100000FFAFB25EDD99F6BF803FEEDECD4C4B40)
2	Durham	("{1,2}",0101000020E610000001F8C47D47B8F6BF00D75B3DA04C4B40)
3	Durham	("{1,3}",0101000020E610000001D064DC8333F7BF003028BE2F4A4B40)
4	Durham	("{1,4}",0101000020E6100000FEBFE63715BBF7BFC0FB53B849494B40)
5	Durham	("{1,5}",0101000020E6100000013822EA645FF8BFC01811DC28494B40)

Figure 63: County Durham Boundary Points

Or we can get a specific point if the input is a **LINESTRING** or **MULTILINESTRING**.

```
SELECT AsText(ST_PointN(GeomFromText('LINESTRING(1 1,2 2,3 3,4 4)'),2))
```



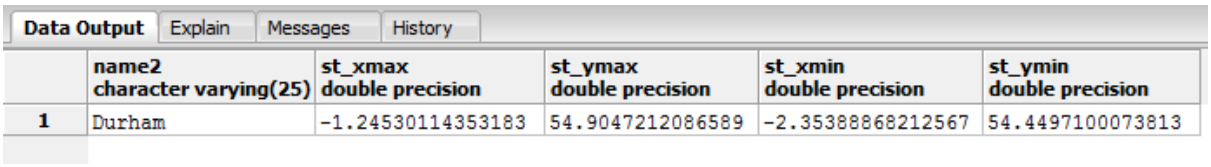
	astext text
1	POINT(2 2)

Figure 64: Finding a Specific Point

The point output shown in the previous figure is the second point in our linestring.

If you need to know the bounding box of an object, you can easily get the *x*, *y* pairs of the maximum and minimum extents by using the following code:

```
SELECT
name2,ST_Xmax(the_geom),ST_Ymax(the_geom),ST_Xmin(the_geom),ST_Ymin(the_geom) FROM
ukcountys WHERE name2 = 'Durham'
```

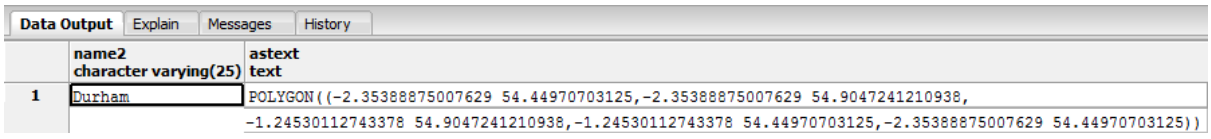


	name2 character varying(25)	st_xmax double precision	st_ymax double precision	st_xmin double precision	st_ymin double precision
1	Durham	-1.24530114353183	54.9047212086589	-2.35388868212567	54.4497100073813

Figure 65: Maximum and Minimum Extents

Or if we need to perform measurements and other functions on our extents, we can get them as an actual geometric rectangle.

```
SELECT name2,AsText(GeomFromText(box2d(the_geom)::geometry)) FROM ukcountys WHERE
name2 = 'Durham'
```



	name2 character varying(25)	astext text
1	Durham	POLYGON((-2.35388875007629 54.44970703125,-2.35388875007629 54.9047241210938, -1.24530112743378 54.9047241210938,-1.24530112743378 54.44970703125,-2.35388875007629 54.44970703125))

Figure 66: Extents Output as Geometric Rectangle

Lastly, let's imagine we have a segment of a path, represented by the following line:

```
LINE(1 1,10 10)
```

Now let's try to make a new polygon based on a border around that line that is 5 units away.

```
SELECT AsText(ST_Buffer(GeomFromText('LINESTRING(1 1,10 10)'),5))
```

This code gives us the following result:

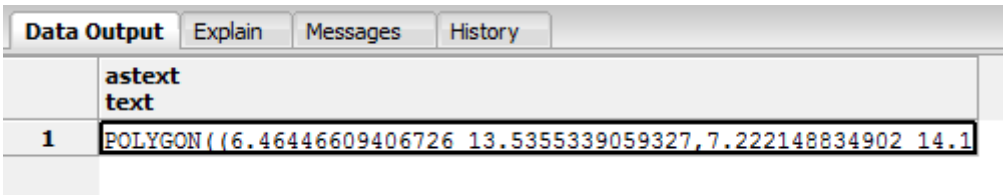


Figure 67: New Polygon Based on Line Segment Border

The output is a polygon with its center line exactly following our line, but 5 units away on all sides.

It's impossible to give examples of every possible scenario and combination in which you can use these spatial functions. The main PostGIS reference can be found at http://postgis.org/docs/reference.html. I encourage you to spend time exploring them and trying the many examples given in the documentation, all of which should be possible using nothing more than pgAdmin's SQL editor.

Chapter 5 Creating a GIS application in .NET

So finally we come to the part most of you have been waiting for: the creation of a small GIS-enabled desktop application in .NET.

In this chapter I use Visual Studio 2010 Ultimate for any screenshots, and my code is in C#.

For anyone who has used any of the Microsoft .NET languages and editors, it shouldn't be much of a problem for you to adapt what I show here to the environment you are working in.

Downloading SharpMap

Before we do anything, we need to download SharpMap; it is the GIS framework we'll be using. Since SharpMap is currently undergoing a lot of changes and general refactoring, it's better to download the source files from SVN and compile your own version than it is to use the pre-compiled downloads.

In your browser, navigate to http://sharpmap.codeplex.com/ and click the **Source Code** tab. Click **Download** to get the latest changeset as a zip file—it's approximately 180 MB. Or you can click **Connect** to get the addresses to connect to either the TFS or SVN repositories using regular clients.

Once you have the sources synced or unpacked onto your hard drive, start Visual Studio, open the **trunk** folder, and open the **SharpMap.sln** solution.

Once everything is loaded, the **Solution Explorer** should appear as it does in the following screenshot:

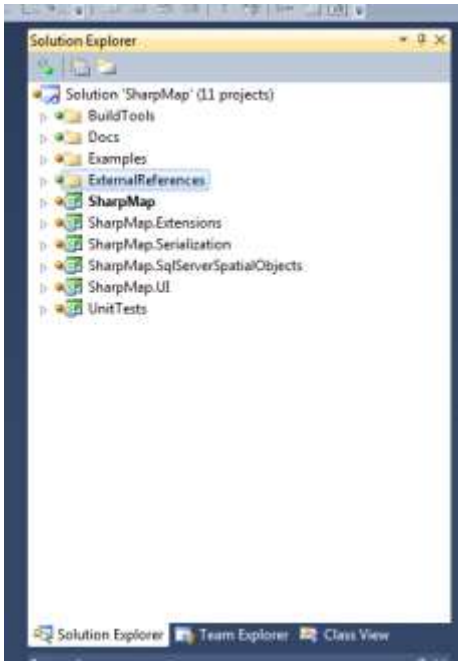


Figure 68: SharpMap Solution

If everything loaded OK, you should be able to click **Build Solution** to get the current binaries. I generally build all the configurations, so I select **Release** then **Build**, **Debug** then **Build**, and so on. What you choose to build is up to you though.

Once everything builds successfully, you're ready to close this project and start on your own.

Creating Our Own SharpMap Solution

Run an instance of Visual Studio or reuse the one you still have open, and create a new Windows Forms app.

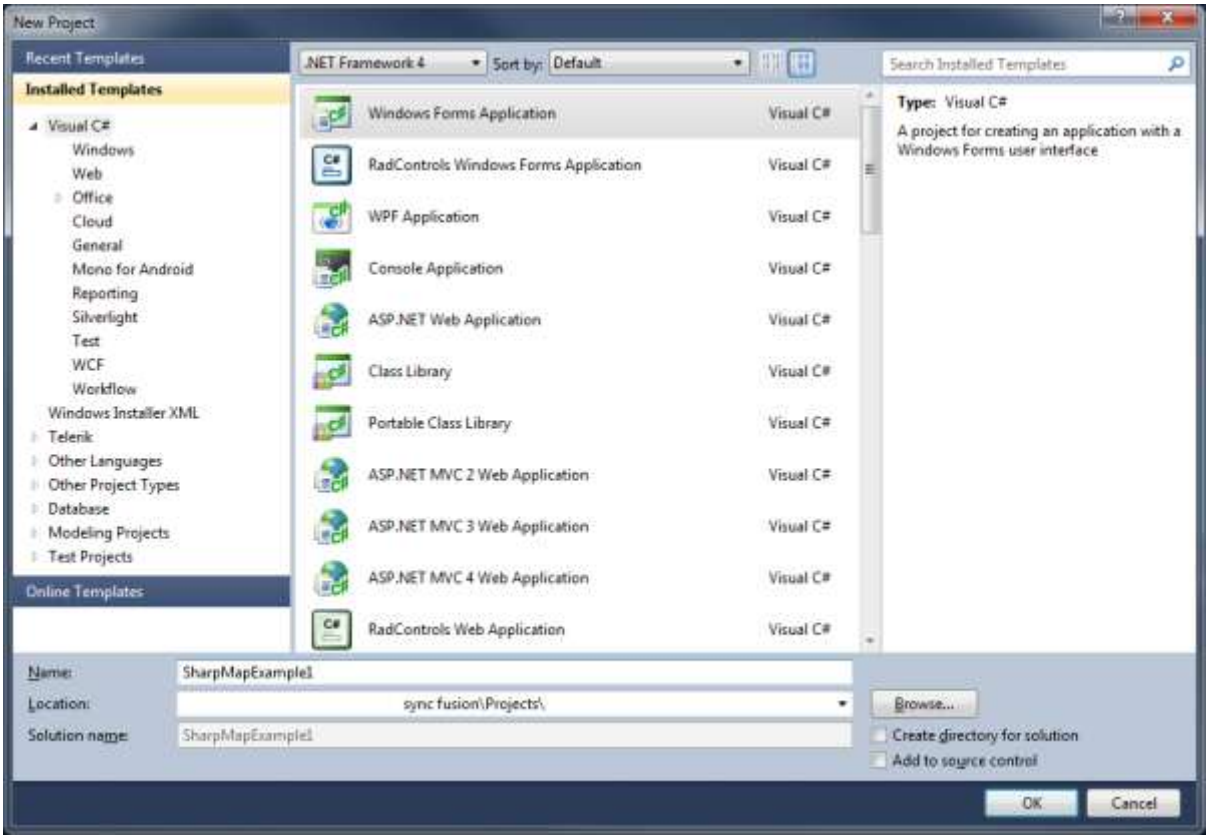


Figure 69: Starting a New Windows Forms App

Make sure you're using .NET 4. The current version of SharpMap is targeted at .NET 4 and above.

The first thing you need to do is double-click on **Properties** in the **Solution Explorer** and change the selected **Target framework** from **.NET Framework 4 Client Profile** to the full **.NET Framework 4**.

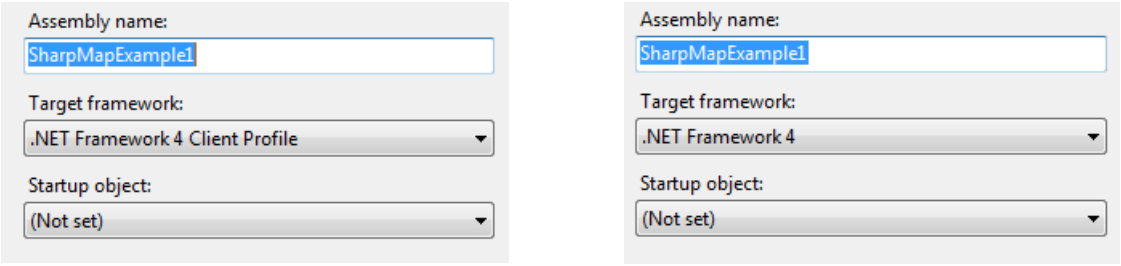


Figure 70: Changing the Target Framework

Now we need to add the SharpMap UI components to our toolbox. Double-click **Form1.cs** in the **Solution Explorer** to load the toolbar palettes. Right-click in an open area below **General** and select **Add Tab**. Give the tab a name. In my application, I called the tab SharpMap.

Once the palette is created, expand it and right-click the **Palette** area. Select **Choose Items** from the menu that appears. The **Choose Toolbox Items** dialog should appear.

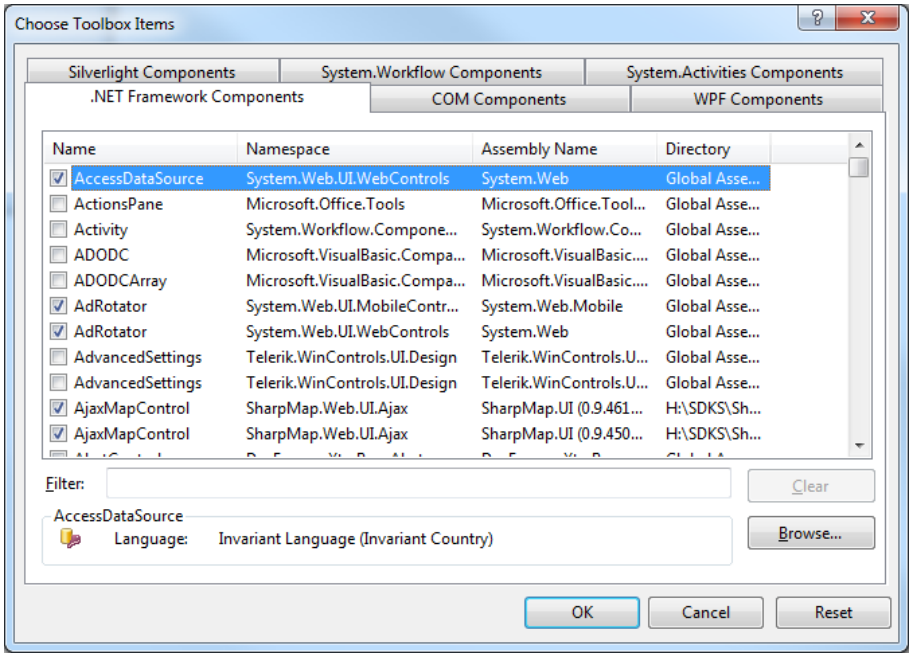


Figure 71: Choosing Toolbox Items

Click the **Browse** button and navigate to the location where you unpacked the SharpMap toolkit. Navigate to **SharpMap.UI** > **bin** > **Debug**, and then select **SharpMap.UI.dll**.

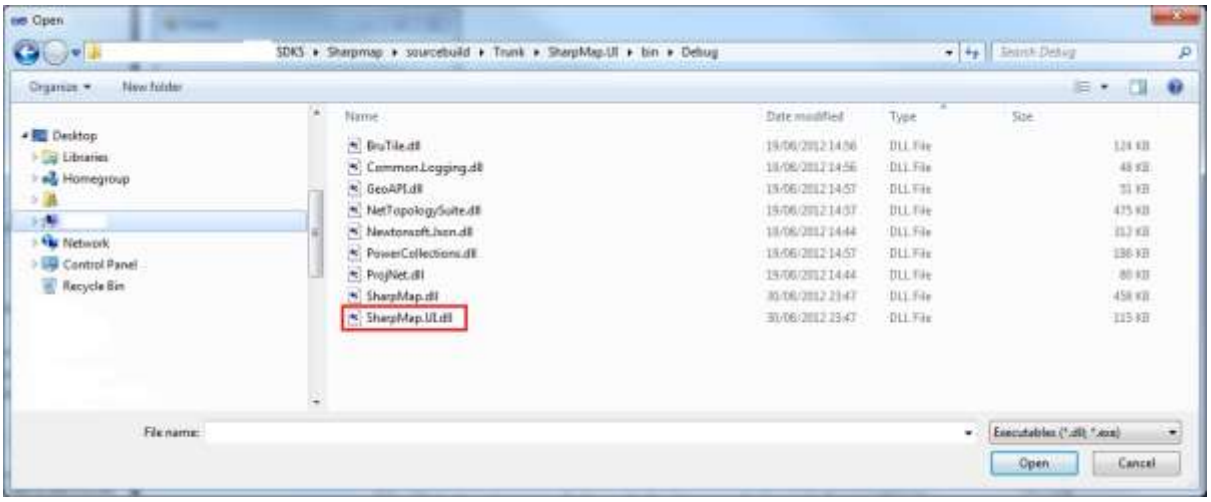


Figure 72: Adding SharpMap to the Toolbox

Click **Open** and then navigate back to the main Visual Studio screen. You should be greeted with the following in your toolbox:

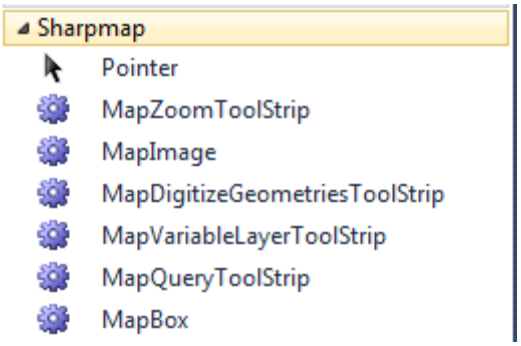


Figure 73: SharpMap and Tools in the Toolbox

You may also find that **SharpMap** and **SharpMap.UI** have been automatically added to your project references. If you started a new project and already had the tools loaded into your toolbox, then you'll need to add the references to your project manually. To do this, right-click **References** in your project, and then browse to the same location where you added the SharpMap.UI.dll. Add the **SharpMap.dll** and **SharpMap.UI** references. After adding these DLLs, reload the **References** dialog.

We need to add some more DLLs which are located in other folders in the solution.

Browse to the **SharpMap.Extensions** project folder, and into **Bin** > **Debug** or **Release** as needed. Select and add the following DLLs:

- BruTile.dll
- GeoAPI.dll
- Npgsql.dll
- SharpMap.Extensions.dll

Your project references should look something like the following screenshot:

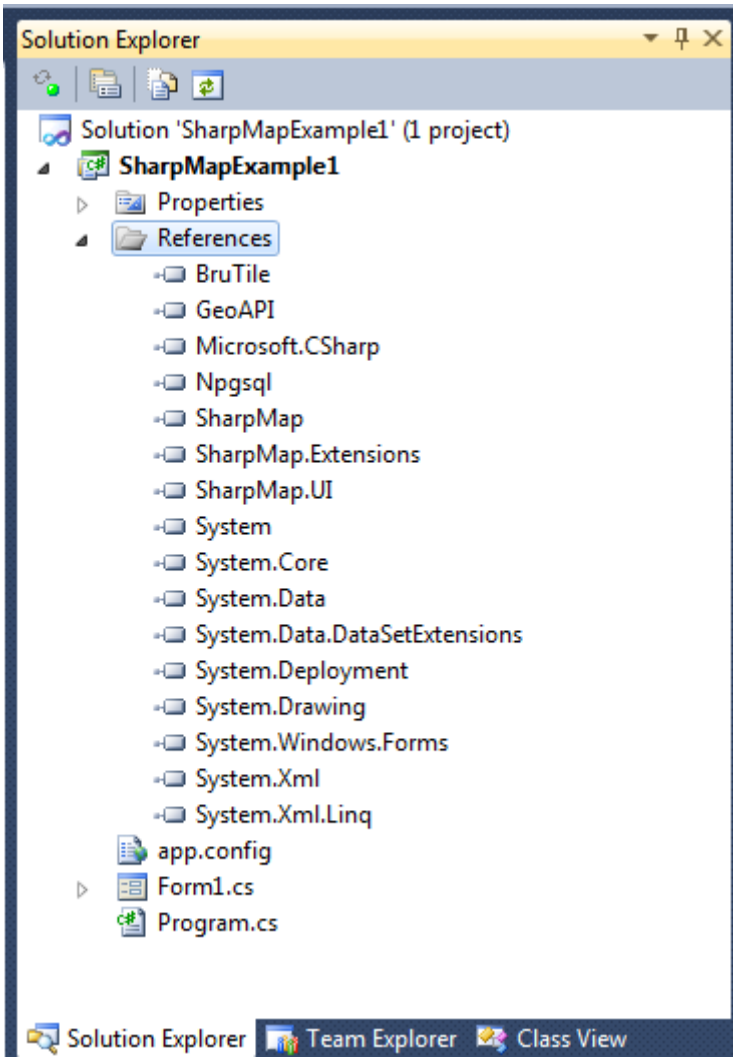


Figure 74: Added References

Now we are ready to put our GUI together.

Set the size of your form to around 1000 x 800, change the **StartPosition** property to **CenterScreen**, and change the title text to **Sharp Map Example 1**.

I generally rename my forms to something like **formMainForm**, but it's entirely up to you what name to choose. If you name your forms something different, you'll need to adjust the source accordingly when we start coding.

Now we need to drag five components onto our form in the designer. They are:

- MapBox from the SharpMap tools.
- Two Button controls and a ListBox from Common Controls.
- StatusStrip from Menus and Toolbars.

Rename the two buttons to **btnZoomAndPan** and **btnQueryCounty**. Change the display text on them to **Switch to Zoom & Pan Mode** and **Switch to County Query Mode**, respectively, and then place them in the upper left corner of your form. Resize them as needed to fit the text.

Select your **StatusStrip** control and rename it **StatusBar**. Then click on the **Items - (collection)** property to launch the **Items Collection Editor**. Click on the drop-down to the left of the status bar and add a **StatusLabel**. Rename the new label as **lblStatusText** and remove the text from the **Text** property.

Set the width of the ListBox control to be the same as the width of the button controls and place it beneath them. Stretch its height to just above the status bar at the bottom. Set the list box's name to **lsbCountyResults**, then click on its **Anchor** property and set it to **Top, Left, Bottom**.

Finally, use the rest of the space on the form for your map box. Align the bottom of it with the list box, and set its **BackColor** property to **White**. Change its name to **mpbMapView**, and change the **Anchor** to **Top, Bottom, Left, and Right**.

Your finished UI should look similar to the following:

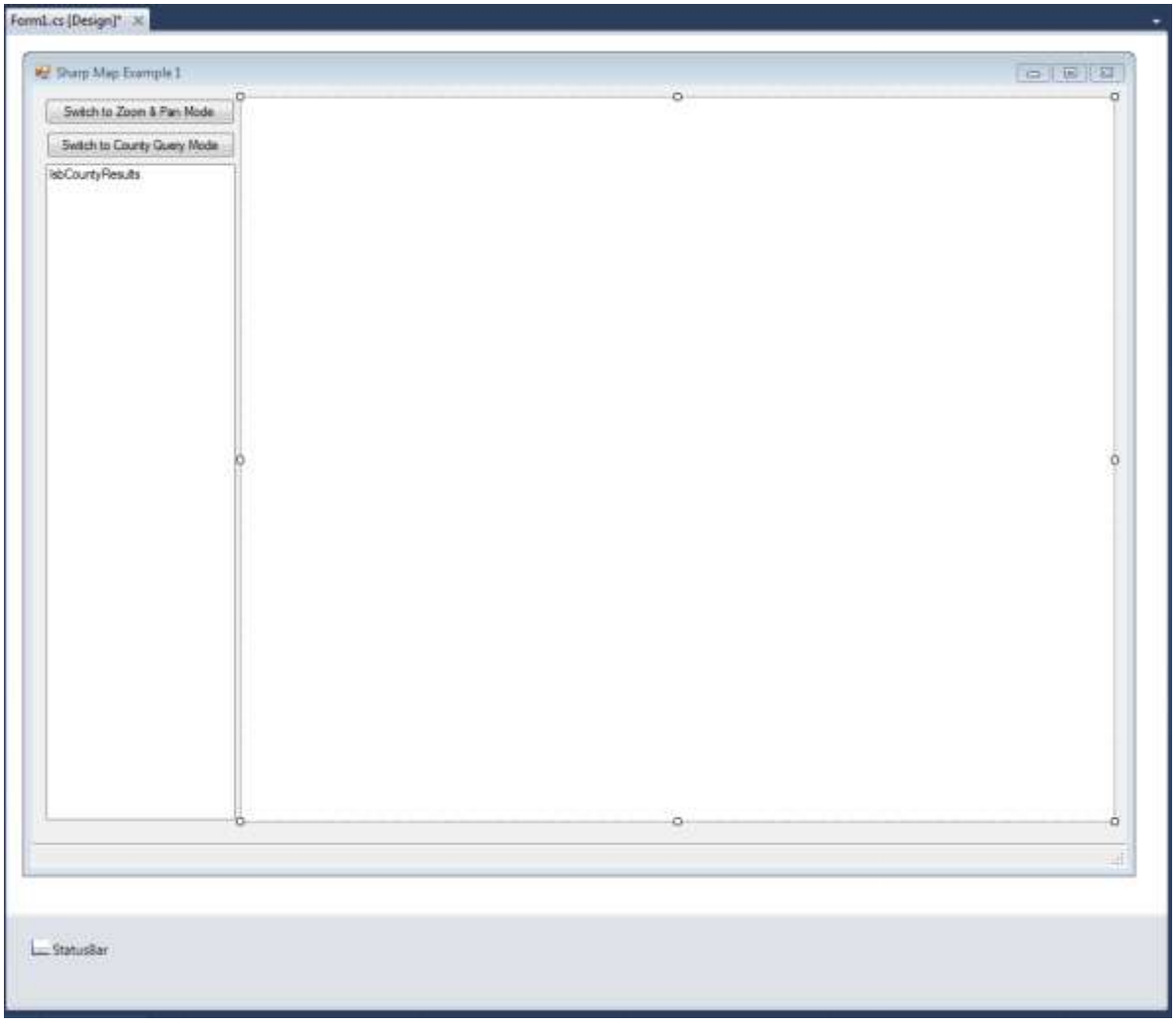


Figure 75: Completed SharpMap UI

Adding the Code

Now that we have a good-looking UI, it's time to start adding functionality to our app.

Using the MapBox control is very easy. The concept is simply to create layers, and then add those layers to the control which will then render and display them.

Each layer can have a different spatial reference and coordinate system, and the map control can re-project and convert coordinates on the fly. For this example though, we're going to let Postgres do all the work for us.

Load and run pgAdmin, and log into your database containing the data we loaded earlier. Expand the object tree until you can see all your tables and other objects.

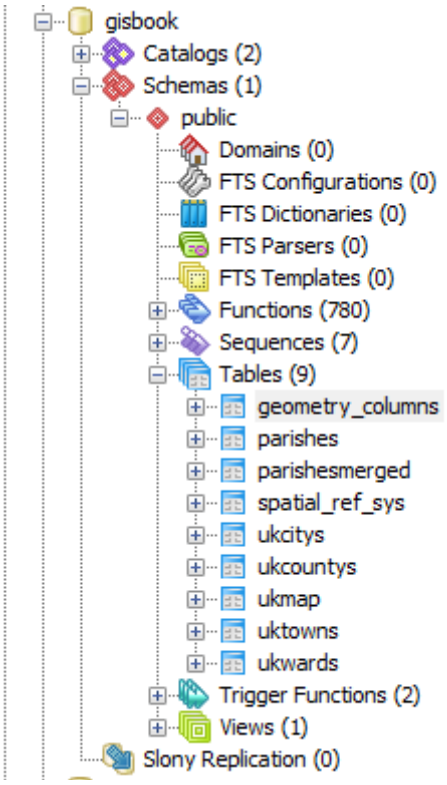


Figure 76: Object Tree in pgAdmin

As you can see in the figure, beneath the **Tables** node is a small green icon named **Views**. You may have used these before in other databases. The general idea is that they project data from other tables into a different schema, but appear to client apps as though they were an actual table.

A typical use is to take rows from different tables linked via foreign keys, and present a simple flat view of the combined data in which all the present items form a single row rather than a hierarchy.

For our demo, we are going to re-project our town and city points as WGS84 (SRID 4326) to match the coordinates of the U.K. counties layer. We'll start by right-clicking on **Views** and creating a new view.

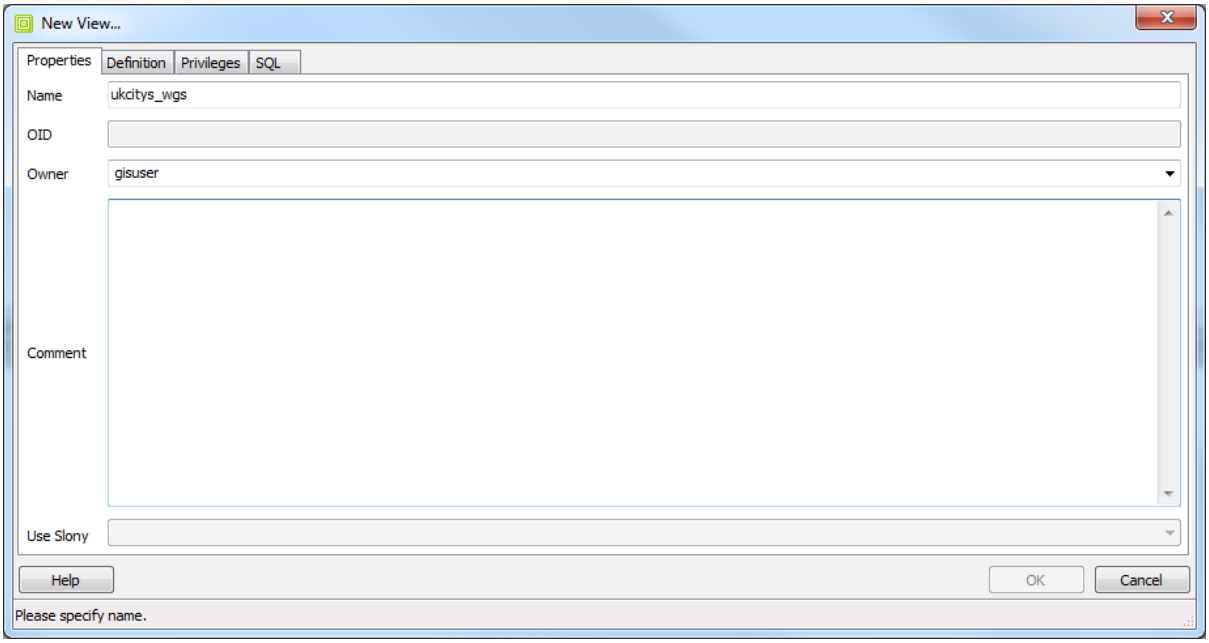


Figure 77: Creating a New View

Give the view a name—I named mine ukcitys_wgs—and set the correct user for your database login.

Switch to the **Definition** tab and enter the following SQL:

```
SELECT ukcitys.gid, ukcitys.number, ukcitys.name, ukcitys.admin_name,
st_transform(ukcitys.geometry, 4326) AS geometry FROM ukcitys;
```

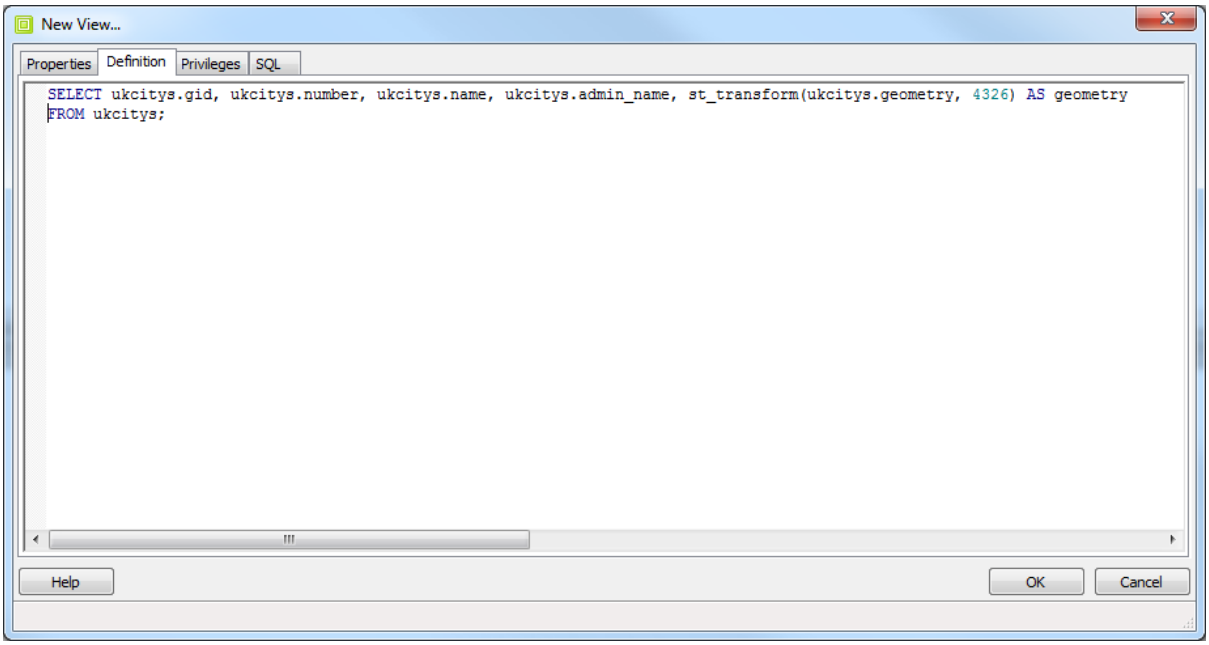


Figure 78: Setting the Database Login

As you can see in our SQL and Figure 78, we are using **ST_Transform** to transform our points from OSGB36 (SRID 27700) to WGS84 (SRID 4326). The result is that when a **SELECT** from ukcitys_wgs is performed, the table layout will be identical to ukcitys, but the geometry will be in the new coordinate system.

Views solve lots of problems like this in a GIS, and you'll tend to find that GIS databases make very extensive use of them.

Repeat these steps and create **uktowns_wgs** using the following SQL:

```
SELECT uktowns.gid, uktowns.number, uktowns.name, uktowns.admin_name,
st_transform(uktowns.geometry, 4326) AS geometry FROM uktowns;
```

One Small Problem...

For all that views do, they do have one small problem when it comes to using them in this way: the spatial metadata.

If you recall the beginning of the book, we discussed the **geometry_columns** table and its importance in the GIS database. When we create tables in the regular table space, we generally use the spatial function **AddGeometryColumn** to add the column that will contain the actual geometry object. You should have seen this happen when you used GeoKettle to add the county data—the SQL that was generated to create the table should have contained the **AddGeometryColumn** spatial function. This not only adds the column and modifies the table as needed, but it also registers the field with the required metadata tables and sets up some triggers to enforce the correct data types and SRIDs.

The problem is because a view is built from existing columns, there is no way of creating an actual geometric column on a view. This means that we have to add it manually. Fortunately, it's not a particularly difficult process; it only involves an insert.

Open up an SQL editor window and enter the following SQL:

```
INSERT INTO
geometry_columns(f_table_catalog,f_table_schema,f_table_name,f_geometry_column,coo
rd_dimension,srid,type)
VALUES('','public','uktowns_wgs','geometry',2,4326,'MULTIPOINT')
```

If you examine the rows already in **geometry_columns**, you'll notice that the data being inserted is identical to the row for **uktowns**; the only difference is the SRID.

To complete this task, perform the following to update for the city view:

```
INSERT INTO
geometry_columns(f_table_catalog,f_table_schema,f_table_name,f_geometry_column,coo
rd_dimension,srid,type)
VALUES('','public','ukcitys_wgs','geometry',2,4326,'MULTIPOINT')
```

Once you are done, you should have the following:

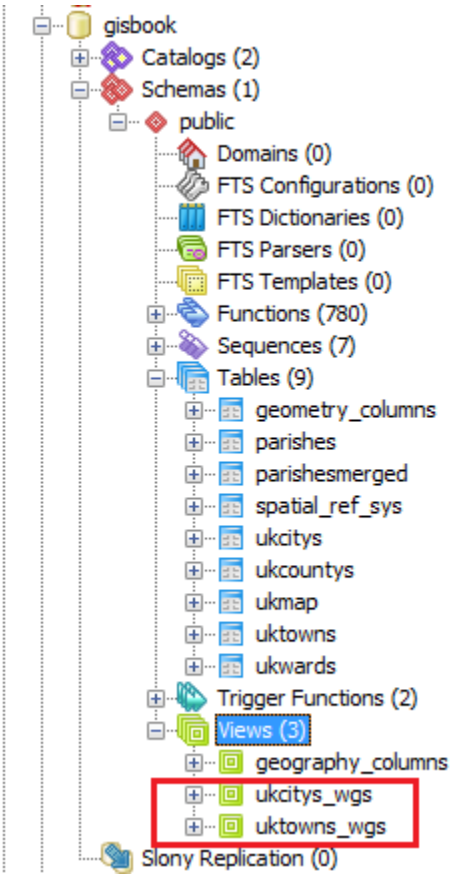


Figure 79: Adding New Views

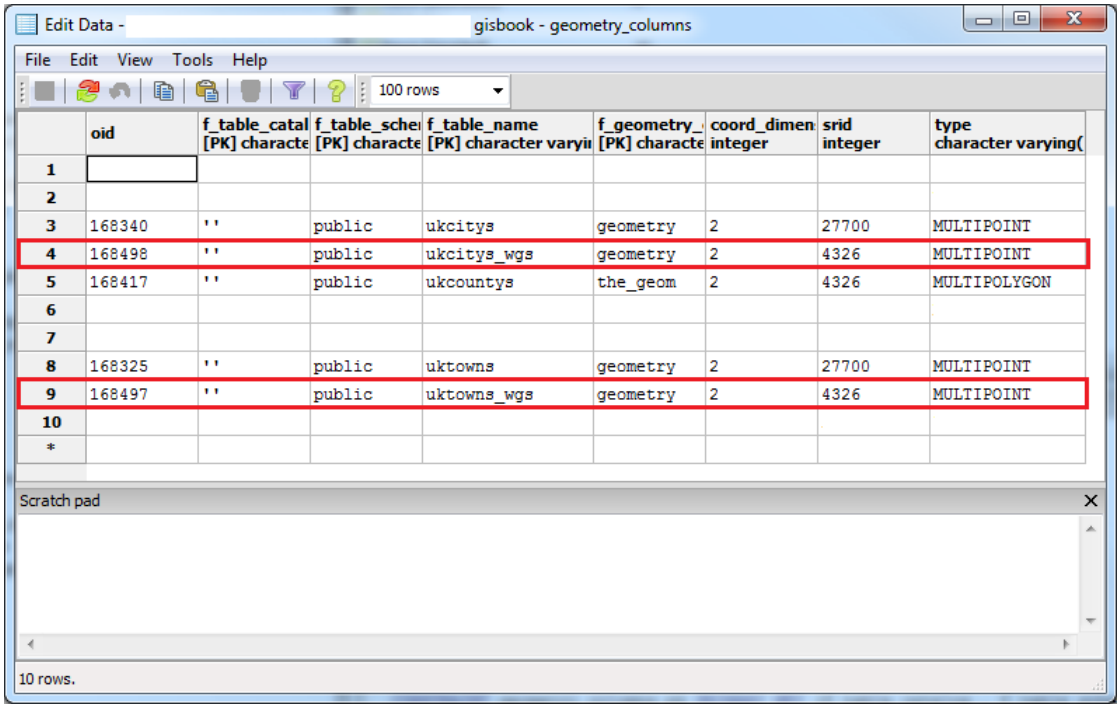


Figure 80: Table with New Views

SharpMap, like any decent implementation of an OGC-compliant GIS database client, will examine the **geometry_columns** table to find out the details of any layers we add. It will cancel and produce an exception if we add a view that can't be found in the geometry_columns table. Once we manually add the data, we can then load those views into our application.

Back to the Code...

Now that we have our UI, our data, and some views to project our data, it's time to add some C# to stitch it all together.

The first thing we need is a connection string for our Postgres database and a Boolean flag for the map initialization. Add the following code just before the constructor for your first form, and substitute the sever name, passwords, and user names as needed for your own connection:

```
private const string _connString = "Server=<server>;Port=5432;User
Id=<user>;Password=<password>;Database=gisbook;CommandTimeout=300";

private bool _mapInitializing;
```

Note that I set the command timeout to five minutes. If you're going to be doing a lot of server-based, long running geometry processing jobs, then this is a wise thing to do. The default command timeout is 20 seconds. When you start doing bigger jobs with this stuff, you'll end up with gigabytes of data and some lengthy run times.

Following our constructor, we need a function for initializing our map to be called from it. Your code should look like this by now:

```
using System.Windows.Forms;

namespace SharpMapExample1
{
  public partial class formMainForm : Form
  {
    private const string _connString = "Server    ;Port=5432;User Id=   ;Password=
;Database=gisbook;CommandTimeout=300";
    private bool _mapInitializing;

    public formMainForm()
    {
      InitializeComponent();
    }

    public void InitializeMap()
    {

    }

  }

}
```

Initializing the map

The first thing we need to do in our map initialization function is set up and load our layers. We'll start with the county layer. The data source for the vector layer requires the names of the geometry column and the primary key—otherwise known as OID or GID in geospatial terms—which you must have in your geometry table, and the name of the table containing your layer.

The code to initialize and load the county layer, give it a green fill, and set a black border style is as follows:

```
const string countyTableName = "ukcountys";
const string countyGeometryColumnName = "the_geom";
```

```
const string countyGidColumnName = "gid";
VectorStyle ukCountyStyle = new VectorStyle { Fill = Brushes.Green, Outline =
  Pens.Black, EnableOutline = true };
VectorLayer ukCountys = new VectorLayer("ukcountys")
{
  Style = ukCountyStyle,
  DataSource = new PostGIS(_connString, countyTableName,
    countyGeometryColumnName,countyGidColumnName),
  MaxVisible = 40000
};
```

We repeat this pattern two more times to load the data for our towns and cities:

```
const string cityTableName = "ukcitys_wgs";
const string cityGeometryColumnName = "geometry";
const string cityGidColumnName = "gid";

const string townTableName = "uktowns_wgs";
const string townGeometryColumnName = "geometry";
const string townGidColumnName = "gid";

VectorStyle ukCountyStyle = new VectorStyle { Fill = Brushes.Green, Outline =
  Pens.Black, EnableOutline = true };

VectorStyle ukCityStyle = new VectorStyle { PointColor = Brushes.OrangeRed };
VectorLayer ukCitys = new VectorLayer("ukcitys")
{
  Style = ukCityStyle,
  DataSource = new PostGIS(_connString, cityTableName, cityGeometryColumnName,
    cityGidColumnName),
  MaxVisible = 40000
};

VectorStyle ukTownStyle = new VectorStyle { PointColor = Brushes.DodgerBlue };
VectorLayer ukTowns = new VectorLayer("uktowns")
{
  Style = ukTownStyle,
```

```
  DataSource = new PostGIS(_connString, townTableName, townGeometryColumnName,
    townGidColumnName),
  MaxVisible = 40000
};
```

The only difference here is that we set the point color rather than the fill and line colors as we do for a polygon layer. We set the **`Style`** property of the layers to our **`VectorStyle`** object to give the layers their visual appearance. Next, we set the **`DataSource`** property to a connection to our Postgres server using the constants and connection string we previously defined. **`MaxVisible`** is the maximum zoom level that objects will be visible at in our map viewer. If we zoom beyond the value we specify, nothing will be drawn on the screen.

After we define the layers and their styles and connections, we then simply add these layers to the map control on our form.

```
mpbMapView.Map.Layers.Add(ukCountys);
mpbMapView.Map.Layers.Add(ukCitys);
mpbMapView.Map.Layers.Add(ukTowns);
```

Then we set our default tool, zoom to the full extents of the map, and render it.

```
mpbMapView.ActiveTool = MapBox.Tools.Pan;
mpbMapView.Map.ZoomToExtents();
mpbMapView.Refresh();
```

We'll finish by inserting the following code as the first two lines of the function; this will add a status message to our status bar while the map is initializing:

```
_mapInitializing = true;
lblStatusText.Text = "MAP Initializing please wait";
```

Your code should now look something like the following image:

```
public void InitialiseMap()
{
  _mapInitialising = true;
  lblStatusText.Text = "MAP Initialising please wait";

  const string countyTableName = "ukcountys";
  const string countyGeometryColumnName = "the_geom";
  const string countyGidColumnName = "gid";

  const string cityTableName = "ukcitys_wgs";
  const string cityGeometryColumnName = "geometry";
  const string cityGidColumnName = "gid";

  const string townTableName = "uktowns_wgs";
  const string townGeometryColumnName = "geometry";
  const string townGidColumnName = "gid";

  VectorStyle ukCountyStyle = new VectorStyle { Fill = Brushes.Green, Outline = Pens.Black, EnableOutline = true };
  VectorLayer ukCountys = new VectorLayer("ukcountys")
  {
    Style = ukCountyStyle,
    DataSource = new PostGIS(_connString, countyTableName, countyGeometryColumnName, countyGidColumnName),
    MaxVisible = 40000
  };

  VectorStyle ukCityStyle = new VectorStyle { PointColor = Brushes.OrangeRed };
  VectorLayer ukCitys = new VectorLayer("ukcitys")
  {
    Style = ukCityStyle,
    DataSource = new PostGIS(_connString, cityTableName, cityGeometryColumnName, cityGidColumnName),
    MaxVisible = 40000,
  };

  VectorStyle ukTownStyle = new VectorStyle { PointColor = Brushes.DodgerBlue };
  VectorLayer ukTowns = new VectorLayer("uktowns")
  {
    Style = ukTownStyle,
    DataSource = new PostGIS(_connString, townTableName, townGeometryColumnName, townGidColumnName),
    MaxVisible = 40000,
  };

  mpbMapView.ActiveTool = MapBox.Tools.Pan;
  mpbMapView.Map.Layers.Add(ukCountys);
  mpbMapView.Map.Layers.Add(ukCitys);
  mpbMapView.Map.Layers.Add(ukTowns);
  mpbMapView.Map.ZoomToExtents();
  mpbMapView.Refresh();
  |
}
```

Figure 81: Nearly Completed Code

Lastly, add a call to **`InitializeMap()`** to your form constructor just below the call to **`InitializeComponent()`**, and that's all that's needed for the initialization function.

If you run your app at this point, and everything has been set up correctly, you should see your map layers appear on screen. You should be able to pan them by dragging the pointer around the map surface, and zoom using the mouse wheel.

It should look something like this:

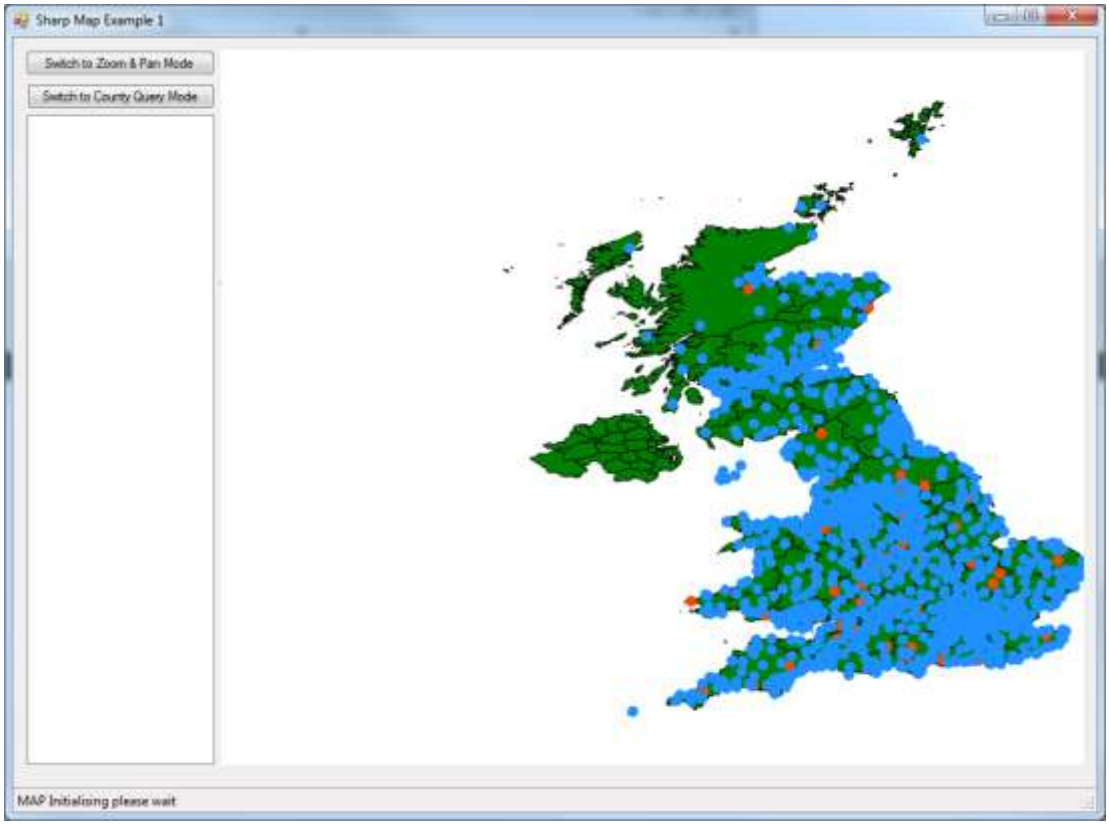


Figure 82: Completed Map

Fixing the Status Label

You'll notice that the **MAP Initializing** message in the status bar never changes. We'll fix that. When the map finishes rendering, it fires an event called **MapRefreshed**.

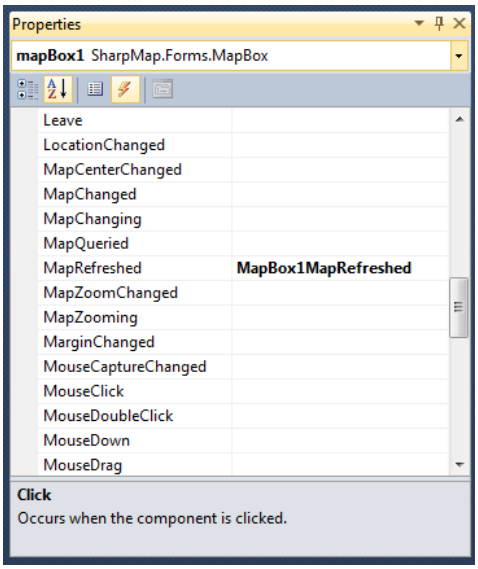


Figure 83: Map Events

We hook this event in our code and add some code to it to change the label. However, we also need to use our Boolean variable to control it as we don't want it called every time our map is refreshed (which will happen quite often).

Hook the event with the following code:

```
private void MapBox1MapRefreshed(object sender, EventArgs e)
{
  if(_mapInitializing)
  {
    _mapInitializing = false;
    lblStatusText.Text = "MAP Initialized";
  }
}
```

If you run it now, the status bar should update when the map has finished rendering.

Wiring up the Tool Buttons

Now we'll add the code for the two buttons that allow you to switch tools.

SharpMap has a number of different tool modes, from zooming and panning to drawing lines and polygons over the top of your loaded map.

The two tools we'll use in this app are the zoom and pan tool, which is the default, and the query tool.

Changing the tool is as simple as assigning a new value to the **`ActiveTool`** property of the **`MapBox`** control on your form. The value to assign is any of the values from the **`MapBox.Tools`** type enumeration.

Double-click on each button in turn and add the following code in each of their click handlers as follows:

```
private void BtnZoomAndPanClick(object sender, System.EventArgs e)
{
  mpbMapView.ActiveTool = MapBox.Tools.Pan;
}

private void BtnQueryCountyClick(object sender, System.EventArgs e)
```

```
{
  mpbMapView.ActiveTool = MapBox.Tools.Query;
}
```

If you run the app now, you should be able to change modes using the two buttons in the top left of the form. Zooming and panning are handled automatically. For queries, we have to respond to the click event on the map box and add some code to get the results we need.

Adding Our County Info Query Code

The first thing we need to do is make sure we are using the **`Query`** tool and go no further if we are not.

From the designer, find the **`Click`** event on the map control and add the following line to the event handler in the code:

```
if (mapBox1.ActiveTool != MapBox.Tools.Query) return;
```

Why do it this way? That's a very good question, especially considering that the query tool actually has its own event handler that is fired when the map is clicked.

While writing this book, I originally used the dedicated handler, but found it quite difficult to narrow down its range and the items I was selecting. Instead of one polygon, I routinely received what seemed like half of the database, and had a difficult time sifting through the amount of data handed to the event handler.

After a bit of research, it appears that most of the examples and recommended ways of avoiding this problem involve trapping either the **`MouseUp`** and **`MouseDown`** events, or the **`Click`** event. I chose the **`Click`** event for simplicity.

Once we know that we're in the correct tool, we can see where we are on the map. The first thing we must do is get the actual mouse position in pixels. Then, we use **`ImageToWorld`** from the SharpMap toolkit to transform the mouse position's *x* and *y* values into a WGS84 latitude and longitude.

Next, we need to use that position to query our county layer and gather a **`FeatureDataSet`** containing any polygons that are present in the location we clicked.

```
FeatureDataSet selectedGeometry = new FeatureDataSet();
VectorLayer theLayer =
  (VectorLayer)mapBox1.Map.FindLayer("ukcountys").FirstOrDefault();

if (theLayer != null)
```

```
{
  if (!theLayer.DataSource.IsOpen)
  {
    theLayer.DataSource.Open();
  }

  Envelope boundingBox = new Envelope(wgs84Location.CoordinateValue);
  if (Math.Abs(boundingBox.Area - 0.0) < 0.01)
  {
    boundingBox.ExpandBy(0.01);
  }

  theLayer.DataSource.ExecuteIntersectionQuery(boundingBox, selectedGeometry);
  theLayer.DataSource.Close();
}
```

This should result in our **FeatureDataSet** collection being filled with any geometry found at that location, which in our case should be the county that we clicked on.

Next up, we need to check if we have any data in the **FeatureDataSet**. If we do, grab the name of the county that was clicked on.

Each row in the **FeatureDataSet** is pretty much the same as a row in a normal data set, so we can look for a column with the same name as a column in the underlying table in Postgres. If no rows are found, it's better to return.

```
if (selectedGeometry.Tables[0].Count <= 0) return;
string countyName = selectedGeometry.Tables[0].Rows[0]["name2"].ToString();
```

Once we have a county name from our U.K. counties layer, we then want to get a list of cities and towns for our county. We do this with the following two methods:

```
List<string> cityList = GetCitysForCounty(countyName);
List<string> townList = GetTownsForCounty(countyName);
```

Now that we have our data, we want to provide some visual feedback to the user. First, we'll highlight the county we clicked on.

```
VectorLayer highlightLayer = (VectorLayer)
  mpbMapView.Map.FindLayer("highlight").FirstOrDefault();

if (highlightLayer == null)
{
  Color myColor = Color.FromArgb(64,144,238,144);
  Brush fillBrush = new SolidBrush(myColor);

  highlightLayer = new VectorLayer("highlight");
  VectorStyle highlightStyle = new VectorStyle
    {Fill = fillBrush, Outline = Pens.White, EnableOutline = true};

  highlightLayer.Style = highlightStyle;
}
```

We do this by first checking to see if we already have a highlight layer on our map. If one is not present, create a new one. One thing to note about setting the style on the highlight layer is the way we set the color. We use the full ARGB color call so that we can specify a transparency level to our layer—the first value in the function, **64**—that allows us to see the existing map elements underneath it.

Next we take the **FeatureDataSet** we obtained earlier and assign it as the data source for our highlight layer so that the selected county polygon shows up with our defined semi-transparent style. Note that this will highlight multiple polygons if you select more than one on the map. Previously selected counties will be cleared.

```
highlightLayer.DataSource = new GeometryProvider(selectedGeometry.Tables[0]);
mpbMapView.Map.Layers.Add(highlightLayer);
mpbMapView.Refresh();
```

Once we add the highlight layer and refresh the map, our selected county should be visible.

The last thing to do for our country query feature is add our county info to the list box on the left of our UI, and add some code at the start and end of the method to show what's happening in our status bar.

```
lsbCountyResults.Items.Clear();
lsbCountyResults.Items.Add("Selected county: " + countyName.ToUpper());
lsbCountyResults.Items.Add("");
```

```
if (cityList.Count > 0)
{
  lsbCountyResults.Items.Add("Citys in this county");
  foreach (string city in cityList)
  {
    lsbCountyResults.Items.Add(city);
  }
  lsbCountyResults.Items.Add("");
}

if (townList.Count > 0)
{
  lsbCountyResults.Items.Add("Towns in this county");
  foreach (string town in townList)
  {
    lsbCountyResults.Items.Add(town);
  }
  lsbCountyResults.Items.Add("");
}
```

Next, we add the status bar message just after the first **`if`** statement.

```
lblStatusText.Text = "Querying Map... please wait for results.";
Application.DoEvents();
```

And we add the completed message just before the closing brace.

```
lblStatusText.Text = "Query finished.";
```

Before we go any further, some of you will say, "Wow, what a long method," and wonder why I'm using **`Application.DoEvents`** to make sure the label is updated in an event handler. Please remember that this is example code only; it's not supposed to be a perfect example, or simply copy and pasted verbatim to make production-quality apps. Its purpose is purely to show you how to use SharpMap to create a simple GIS application.

Conclusion

The final thing we need to do is create the two methods to retrieve our city and town lists from our GIS database.

SharpMap is perfectly capable of taking the polygon outline we found earlier and querying the other layers in the map to tell us which points fall within which area. However, as this book is primarily about using a GIS database, I'd like to conclude by letting Postgres do the heavy lifting for us once more.

The two methods are fairly similar, so I've copied both of them out and just described them as one.

```
private static List<string> GetTownsForCounty(string countyName)
{
  string sql =
    string.Format(
      "SELECT t.Name FROM ukcountys c, uktowns t WHERE name2 = :county AND
       ST_Within(t.geometry,ST_Transform(c.the_geom,27700))");

  List<string> results = new List<string>();

  using (NpgsqlConnection conn = new NpgsqlConnection(_connString))
  {
    conn.Open();
    using (NpgsqlCommand command = new NpgsqlCommand(sql, conn))
    {
      command.Parameters.Add(new NpgsqlParameter("county", NpgsqlDbType.Varchar));
      command.Parameters[0].Value = countyName;

      using (NpgsqlDataReader dr = command.ExecuteReader())
      {
        while (dr.Read())
        {
          results.Add(dr.GetString(0));
        }
      }
    }
  }

  return results;
```

```
}

private static List<string> GetCitysForCounty(string countyName)
{
  string sql =
    string.Format(
      "SELECT t.Name FROM ukcountys c, ukcitys t WHERE name2 = :county AND
       ST_Within(t.geometry,ST_Transform(c.the_geom,27700))");

  List<string> results = new List<string>();

  using (NpgsqlConnection conn = new NpgsqlConnection(_connString))
  {
    conn.Open();
    using (NpgsqlCommand command = new NpgsqlCommand(sql, conn))
    {
      command.Parameters.Add(new NpgsqlParameter("county", NpgsqlDbType.Varchar));
      command.Parameters[0].Value = countyName;

      using (NpgsqlDataReader dr = command.ExecuteReader())
      {
        while (dr.Read())
        {
          results.Add(dr.GetString(0));
        }
      }
    }
  }

  return results;
}
```

Anyone who has done any raw ADO.NET programming should immediately recognize what we are doing here, and may even quite reasonably ask why we're not using LINQ to SQL, or Entity Framework, or…the list goes on.

In the first place, the raw Postgres data provider doesn't provide an Entity Framework or LINQ-to-SQL data model provider. Secondly, since we're using spatial functions, it's far better to do this in ADO.NET than in a model where the SQL-level syntax is deeply hidden from view.

The first thing we do is make a constant string of the SQL we wish to run in the database, and I'd like you to pay particular attention to **`:county`** in the query string. This is one of the places where the Postgres data provider differs from the regular ADO.NET way of providing parameters to a query string.

In regular ADO.NET code, parameters are usually prefixed with **`@`**, e.g., **`@county`**. In Postgres, parameters are prefixed with a **`:`**. In code, however, adding parameters is done in the same way.

The rest is fairly self-explanatory. We open a connection using the connection string we defined previously, open the database, add the parameter, and run our SQL before finally getting a data reader object to read our results into a generic string list.

We're doing all of this in nested **`using`** statements, which means everything is **`IDisposable`** and should be freed correctly once we're done, leaving us to simply return the string list of results back to the calling method.

If everything goes according to plan, on clicking **Run** you should be greeted with an application that can zoom and pan around the map defined in your database, as well as switch to **`County Query Mode`** and retrieve a list of towns and cities in a selected county. Your finished app should look something like the following:

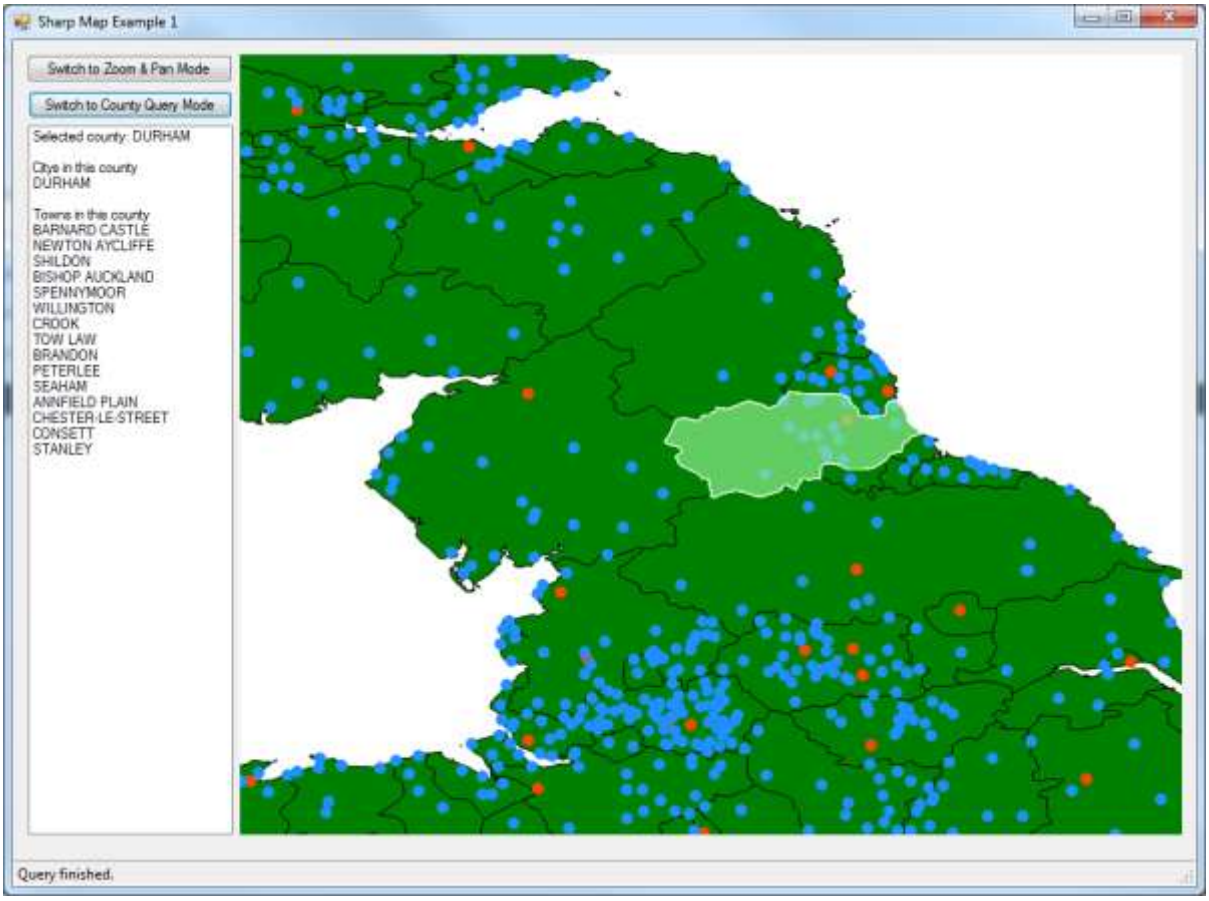


Figure 84: Completed Map Application

And there we have it. Hopefully I've whetted your appetite and shown you just a few of the many things GIS can help you with in daily life.

Remember that it's possible to buy mobile phones that have enough power to do this kind of thing on a small scale, and there are database systems to support them such as SQL Compact. SharpMap allows you to do everything from vector to raster maps and beyond. Once you start looking further, you'll find that some systems have the built-in ability to read GPS devices, enabling you to pull real-time location information into your apps. Go out there and explore the world in both its real and digital forms. It's an adventure that's only just started.

Acronyms and Abbreviations

I thought it would be pertinent to leave you with a list of some of the acronyms you've seen throughout the book. Like any industry, there are many acronyms to be familiar with, and even though I've tried to explain them where possible, a summary list never hurts.

EPSG
European Petroleum Survey Group

ESRI
Environmental Systems Research Institute

EWKT
Extended well-known text

GIS
Geographic information system

GML
Geography markup language

GPS
Geographic positioning system; geographic positioning satellite; global positioning system

KML
Keyhole markup language

NMEA
National Marine Electronics Association

OGC
Open Geospatial Consortium

OSGeo
Open Source Geospatial Foundation

SRID
Spatial reference identifier

WKB
Well-known binary, the binary format of data in a GIS database

WKT
Well-known text, the text format of data in a GIS database