THE USE OF GIS IN LAW OF THE SEA

UKHO has been using the CARIS LOTS application for virtually all aspects of LOS work over the last 12 months and has seen the application develop considerably during that time. It has taken time and ingenuity to develop confidence in the methodology of the application and the accuracy of results. In addition, it has taken time to build trust in a system that will produce answers to complex questions at the touch of a single button. Using GIS also presents considerable problems in the assembly of a suitable digital model from which solutions can be calculated. From the perspective of someone who learned to solve problems in longhand, this paper reflects on learning to trust GIS and how to make the most of the benefits it has to offer.

ACCURACY

In broad terms, a suitable GIS application should allow the generation of rigorous solutions to all the likely scenarios encountered by the LOS practitioner and should display these as a computer graphic image viewed alone or superimposed upon other world, chart or map images. The choice of system is paramount, many GIS applications focus only on the need to produce illustrations and do not produce accurate answers. A system suitable for Law of the Sea must generate solutions using suitably rigorous geodetic techniques and must be able to do more than generate a computer graphic as the result. The ability to output graphics to a properly scaled and accurately projected chart is essential and the ability to report calculated co-ordinates for lines and points is also essential.

CARIS LOTS has been used widely in UKHO and from the outset, considerable care has been taken to ensure the application is providing accurate results, however, it is not a simple matter to put so complex an application through a set of rigorous tests. Tests of the solution against previously worked calculations show no significant differences. Specific tests to compare the calculation of a tri-point, the intersection of geodetic range arcs and the length and azimuth of geodesic and rhumb lines between fixed points have shown no differences at all from the normal geodetic tools used in UKHO. However, such testing is not exhaustive as in many instances, a solution generated from GIS is derived graphically. For example, the point of intersection of a 200 mile arc with a geodesic joining 2 fixed points can be calculated but with GIS, the simple approach to the problem is to generate the arc and input the geodesic then extract the co-ordinates of the visible point of intersection. There is no need to enter lengthy calculation, no need to extract a trial point to avoid calculating the wrong intersection point, the answer is clearly visible but the user must have faith in the processes used by the GIS display.

The example given is relatively straightforward and it is clearly possible to approach the question from first principles and check the result, however, with faith in the processes, it is possible to approach more tricky problems with confidence. Take a 12M limit, by definition measured on the spheroid, generated from an archipelagic baseline which is over 100 miles long but defined as a loxodrome. Try to calculate the precise point at which this limit intersects a meridian or parallel and many eyes glaze over when trying to deduce such co-ordinates from first principles. The GIS approach is purely graphic. One can take the loxodrome joining two points and generate intermediate points along the line to any density. One can then produce an envelope of arcs using all these points to generate a very close approximation of the limit. One can now see where this cuts the meridian and extract the co-ordinates. However, to get at the solution, one uses the GIS application to intersect and cut the limit and the meridian, then place a symbol at the intersection, telling the application to snap the symbol to the nearest line end point, then report to a text file the position of the symbol. There is a lot of trust involved here:

- Is an accurate projection used – is there confidence the loxodrome is plotted properly.
- Is the loxodrome sub-divided into a series of points properly and with sufficient precision.
- Have sufficient intermediate points been chosen to avoid forcing significant errors. Too wide a spacing of intermediate points when generating a small limit will give a very “bumpy” limit line.
- Is the intersection of each arc of circle accurately calculated when building the limit line.
- Does the process for generating an envelope of arcs use sufficient points on the arcs to avoid errors in the use of chords when intersecting individual arcs.
- Is the resulting limit line an accurate representation of the envelope of arcs.
- Are sufficient points used to plot the limit line and so avoid further errors from the use of short chords
- Is the meridian or parallel accurately generated on the display
- Does the instruction to intersect and cut the lines produce a precise intersection point
- Does the placement of a mark at the intersection really snap precisely to the line end produced by the intersect and cut
- Is the point accurately reported to the text file.

Add a few more complications:

The archipelagic baseline is chosen from a chart. The chart is a Mercator projection based on an obscure datum. The raster image of the chart is imported into the GIS application and in the process, the application has read data from the chart image header and used this to transform the entire GIS display from WGS84 to the chart so the user may pick accurate positions from the chart whilst continuing to work on a solution based on a WGS84 framework. Having then completed the GIS solution, the intersection point is reported to a text file based on the obscure datum. This introduces another long list of points where the GIS process must be trusted. The chart header defines a simple block shift and testing this aspect of the solution requires patience and ingenuity before one feels entirely confident that data digitised from a chart image ends up as WGS vector data in CARIS. However, when reporting the position to text, the option exists to give CARIS a full set of parameters for the datum and conduct a rigorous transformation. The process works well and although a block shift may seem a little coarse, it is reasonably precisely defined in the chart header data and provides a connection to WGS84 which is well within the limit of accuracy for data extracted from the chart image. There is, however, one interesting twist that has emerged from use of CARIS. It would seem that there is not a uniform convention for quoting the rotations used in a 7-parameter transformation of co-ordinates between datums. Parameters normally accepted as precise in UK require reversal of the sign of the rotations to achieve the correct answer. Apparently, this is a common problem when using North American software with European data.

The point to note is that knowing in theory that your GIS application is approaching the tasks you set with geodetically sound algorithms is only part of the answer to the question “can it be trusted”. It takes time to learn how to use the application and time to build confidence both in your ability to use it to best advantage and the application’s ability to give you a sound answer. It is easier to build confidence when you know the product comes from a company that has a proven track record in the processing of hydrographic data and the building of navigational charts. On the other hand, it is very disappointing to see the results of poorly designed applications. As the UK authority on our maritime limits, we often receive obscure questions from various agencies which have used a poor data set and run it through a flat earth illustrator and found errors in our depiction of maritime limits on UK Charts.

BUILDING SOLUTIONS

GIGO is the theme – garbage in garbage out. However rigorous the GIS application and however much you trust its processes, the quality of a solution will only ever be as good as the data put in. For Law of the Sea, virtually all solutions stem from the baseline and by comparison to the ease and speed with which a GIS application will generate solutions, the task of building the baseline model is exceedingly slow, tedious and difficult.

The starting point for a LOS solution is to assemble published data describing treaties, straight and archipelagic baselines and declared bay closing lines. This data is fairly easily found and the sprinkling of typographic errors in most publications summarising this data are fairly easily spotted, however, the data is seldom easy to use. The game of "guess the datum" is all too common. Sometimes, where treaty lines are only depicted on old small-scale charts as a pencil line, it is impossible to recover a datum. There is a desperate need to try and re-visit many treaties, declarations and other national legislation to attempt make the data more usable by agreeing the source datum, agreeing its connection to WGS84 and publishing the information. The beginning of regional databases to support the new generations of digital chart offers an opportunity to address this question. Will it be done?

With established data imported to GIS, the problem of filling in the remainder of the model using the normal baseline arises. Again, a difficult task. UKHO has the distinct advantage of being able to access a raster chart image for just about anywhere in the world but even so, there is no guarantee that it is the largest scale chart approved by the state whose baseline one is building. Where UKHO is retained by a state to build a solution for delimitation, access to their baseline is possible but the same is probably not true for the other party in the delimitation.

Capturing the baseline data once the correct source is available is a time consuming task but not complicated. Digitising a coastline from Raster images is relatively straightforward once the image has been imported and accurately referenced to the WGS framework. Where paper products are the only source, it is feasible to digitise directly from the paper but this is not accurate, particularly when the chart has been folded a couple of times and pummelled by the postal service. It is preferable to scan the image at 600 dpi to form a TIFF image that can be imported and georeferenced. Incidentally, the ability to import and register tiff images also allows use of satellite images. To improve the speed for capturing the normal baseline, UKHO is currently working towards a trial on another GIS tool that will automatically follow and digitise a continuous black line on a raster image.

To support say, the 12M limit, a full digital model of the normal baseline is not required and a much smaller data set of individual points controlling the limit will suffice. Here GIS helps by providing filters that will extract contributing points from a full baseline model. The same is true for points contributing to a median line solution and by judicious filtering, a complex coast can be dramatically thinned to one that will contain all relevant baseline points. This makes no difference to the accuracy of a GIS output but it will dramatically increase the speed with which limits or median lines are generated. Being able to work out solutions for various options of median line in almost real time is far more conducive to creative thought processes when looking for an acceptable solution to a difficult problem.

The full model of the normal baseline is needed to enable the closure of juridical bays whose closing lines will affect an outer limit. Here again, CARIS offers help. A semi automated routine will allow you to choose a potential bay, choose a potential closing line and automatically check the enclosed area meets the rules. The process is accurate and is particularly useful where the area is critically close to the limit or where closing lines are broken. However, these calculations clearly need a full precision model of the normal baseline inside the bay and it adds considerably to the time taken to build the model.

Building the baseline model is a slow and tedious process but it is the foundation of all other work we do. It is particularly depressing to be called into a negotiation after the process has started when politicians need instant appreciation of proposals. Faced with this situation it is necessary to make assumptions and use unsuitable source data to produce an illustration of a proposal, always working with the caveat that the answers produced will need to be re-calculated when bilateral agreement is reached on the baseline data to be used. In my view, technical experts should have a clear run at any task involving delimitation, with several weeks' collaboration to exchange and verify data on the opposing baseline models, before any talks take place. Advice then given in negotiations can at least be based on the real world!

One note of warning. There are a large variety of packaged data sets that may offer a quick solution to the task of building the baseline model. Although UKHO has not undertaken an exhaustive trial of these, from what has been seen, we tend to the opinion that whilst they may be useful for illustrative work on a very small scale, they are totally inadequate a basis for calculating accurate limits or median lines.

A few years ago, the task of assembling the data needed for a solution was the easy bit. Drawing it onto paper charts and plotting limits was a very slow process. Manually selecting basepoints and constructing a true median line by trial and error was an interesting challenge, but it could take several days. In broad terms, for a complex LOS picture, GIS allows you to complete in a day more than could be accomplish in a week using manual methods. Moreover, providing you check the input of source data and understand your GIS, there are very few opportunities for calculation or transcription errors and the result is a clear, precise digital image.

3-DIMENSIONAL DATA

So far, this paper has dwelt on the use of GIS to generate line solutions on the spheroid. As many of you are aware, CARIS also provides an integrated tool to examine data defining water depth or sediment thickness and to use this in an integrated programme to examine the outer limit of the continental shelf. It is not appropriate here to write a tutorial on how to use CARIS to solve your Article 76 solution, you may go direct to CARIS for chapter and verse on that issue. Suffice it to say that having built a framework of baseline model, median lines and limits, you also have the facility to import both raster images and simple profiles of x,y,z data to look at bathymetry and sediment thickness. This in turn allows you to select points to define the foot of the slope and the Gardiner line and to examine bathymetric contours. With the baseline, the 2500m contour, a line representing the foot of the slope and the Gardiner line, all the claim lines and cut off lines can be generated, then cut and spliced together to produce the outer claim line.

One important facility of CARIS is the ability to import swath bathymetry and generate a gridded data set for analysis of either of bathymetry or sediment thickness. CARIS works with a square grid and UKHO has encountered some difficulty with other processes that seem only to be able to generate a data set gridded to a fixed geographical interval of, say, 0.1 minute of latitude and longitude. In this example, importing ready gridded data to CARIS requires re-gridding into a square grid of, say, 200 metres. It is not entirely clear how re-gridding affects the shape of the bathymetry model and concern is felt that this approach is bound to introduce a distortion. CARIS is working on an improvement to the application to allow direct import of a gridded data set to by-pass the CARIS gridding function, but again, that will only work if the initial gridding is completed on a square grid. Avoiding the problems of the oblong grid is possible if the swath data can be accessed during the processing as a filtered and cleaned set of sounding values before it is then processed into a grid, however, that involves re-processing of raw data and generates a very large data set.

DEVELOPMENT

The versatile ability of CARIS LOTS to generate a wide variety of LOS solutions is made more accessible to the LOS practitioner by provision of a series of single function buttons which will trigger a fairly complex set of GIS commands on the underlying data. Engineering this application has driven CARIS to develop a specialist Law of the Sea tool that uses GIS processes in the background and does not require specialist GIS knowledge. Increasing sales of the product has drawn a broader spectrum of user requirements and seen rapid development developments of the application with more user-friendly functions added and major improvements in the versatility of the tool for the LOS practitioner. Whilst this has made the power of GIS available to those who are not expert in this field, it has also produced an application that presents quite a challenge to the user to develop trust in the processes and solutions it offers.

CARIS have managed to get away from the notion that the customer must learn advanced GIS techniques to use the product effectively and adopted the ideal that they must tailor GIS activities to suit the customer’s requirements. This is a fundamentally different approach to that of many GIS providers who are prepared to charge you a hefty fee whilst their programmers learn your requirements and attempt bespoke development of their application. From an entirely personal point of view, I have not found anyone so prepared as CARIS, to come to the user with innovation to meet their needs – that said, I must admit that since finding CARIS I have not been looking that hard!

In summary, GIS will save enormous amounts of time and money when used by an expert who can trust the solutions it offers. The cost is high but repayment through efficiency can be measured in months rather than years. In the hands of an expert who fully understands the capabilities and limitations of the application, GIS is an extremely powerful tool but it will not turn amateurs into experts.