# GPS and chart errors

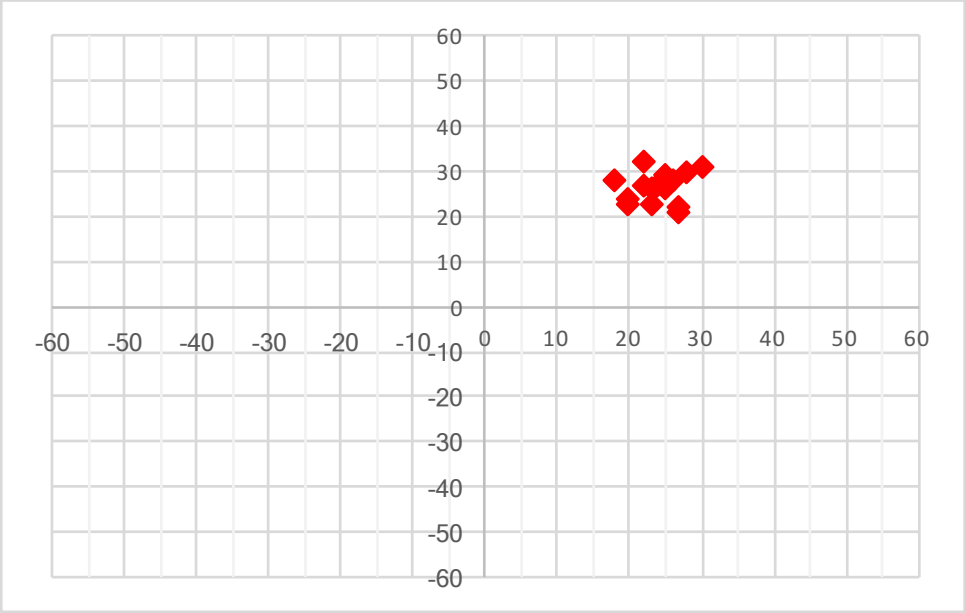
Kim Klaka presented to SoPYC 18th June 2018

## Background

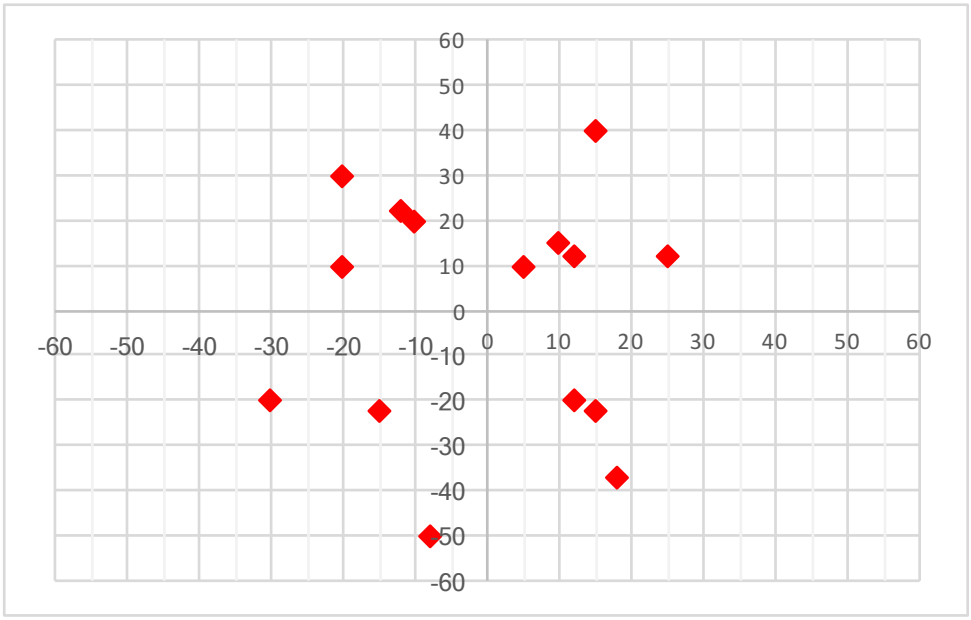
This presentation came about as a result of my role as Editor of the Western Australian Cruising Guide (a free downloadable 600 page book, see references at end). Many readers of the Guide have asked me why the anchorage waypoints and the like are published to only one decimal point (i.e. +-100m accuracy), despite us being sent reports containing waypoints with up to 3 decimal points (i.e. +-1m). Why has this been done? The short answer is that positions are often not accurate to more than one decimal place. This may surprise some people, so a fuller explanation is given below.

## Accuracy or precision?

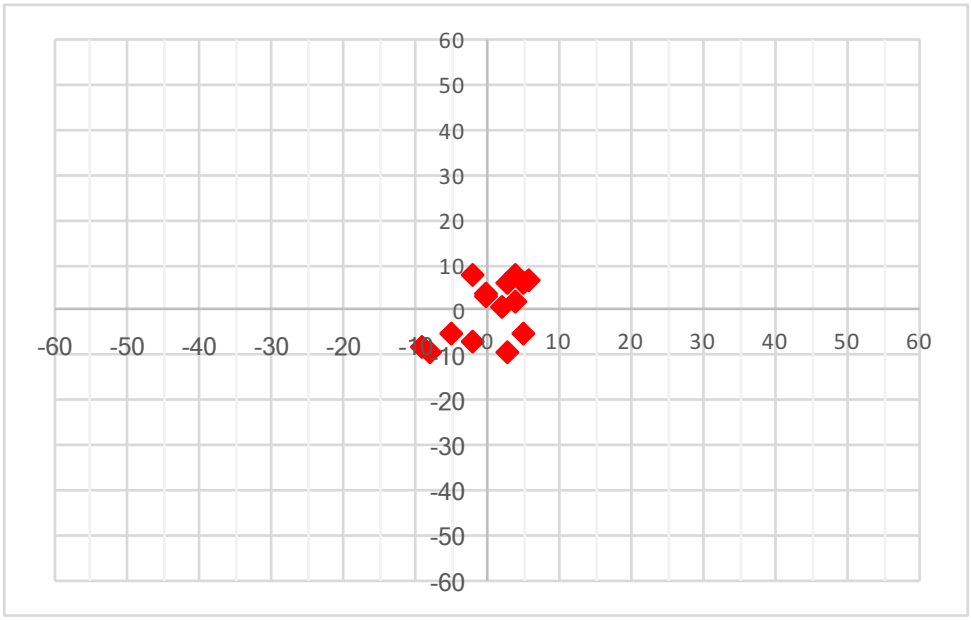
To understand the rationale for publishing waypoints to only one decimal place, we must first appreciate the difference between accuracy and precision. Accuracy is how close a reading is to the truth, whereas precision is how repeatable a reading is. For example, your boat pen might be located at latitude 32° 04.222'S. Your GPS might give its latitude as 32° 04.200'S, which is wrong by 44m (0.022'). That 44m is an estimate of its accuracy. Every time you return to your pen you might check its GPS latitude; perhaps it always gives the same reading to within just 0.002'. That is a precision of 4m, not an accuracy of 4m; the position is still wrong by at least 40m. Many people assume that if a GPS gives them the same reading each time, then that reading is accurate; it is not. Well it might be, but you just don't know. All you can say is that it is precise.



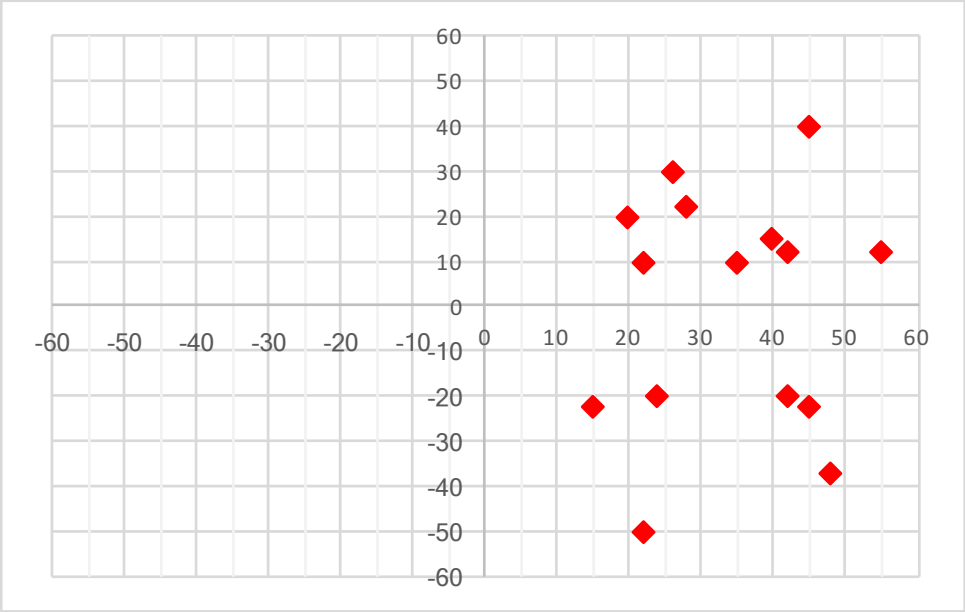

*Precise but not accurate*




*accurate but not precise*




*accurate and precise*




*neither accurate nor precise*

## Error sources

Once the distinction between accuracy and precision is understood, it is possible to start examining the errors and uncertainties in establishing your position on the globe using a GPS. This is a very big topic - the subject of entire books - so the following is a very simplified summary of the chain of errors that make up positional accuracy. I use the term 'error' very loosely, to include inaccuracy, uncertainty and unreliability.

### *GPS errors*

The GPS itself has high accuracy, perhaps less than 5m most of the time. However, it does suffer occasional short-term variations of position by 20m or so ('jumps'). There are lots of reasons for those jumps, we just have to be aware that they exist. The jumps might occur for a few minutes or hours and give a deceptive impression of accuracy. In fact the GPS is giving precise readings between jumps, but the jumping means it is not as accurate as you might assume from the readout. Some of the errors causing jumps and other positional inaccuracies are incorporated in a number called Dilution of Precision (DOP, or sometimes HDOP). This number can be shown on the GPS screen if you dig through a few menu options. If the DOP number is high, the GPS position is inaccurate or unreliable (as a very rough guide, a DOP of 1 is good; 5 is maybe OK; 10 is definitely dodgy). When was the last time you looked at the DOP? Of the hundreds of reports we receive of anchorage waypoints, not one has quoted the DOP of the GPS waypoint submitted. They could be tens of metres out, or just one metre out; we don't know. Nevertheless, this is probably the least of our worries when it comes to finding our position on the globe….

## *Datum errors*

The next link in the error chain is the chart datum used for the chart you are using to plot the GPS position. This can be either a paper chart or an electronic chart, it doesn't matter which. The datum used for the chart has to be the same as that used in the GPS. The most commonly used datum is WGS84, which is within 1m of the GDA94 used for DoT charts. If the wrong datum is used (or not corrected for), errors of a few hundred metres are usually created; the difference between positions for WGS84 and AGD84 is 200m and some chart datums used by other countries have differences from WGS84 of up to 9 miles! Fortunately most sailors using GPS and charts are aware of this problem and take care to ensure the datums correspond. However, as with GPS DOP information, we rarely receive waypoints with a chart datum quoted, let alone a confirmation that that the chart datum corresponds with the GPS datum. Again we can relax a little because even this is not the biggest source of concern….

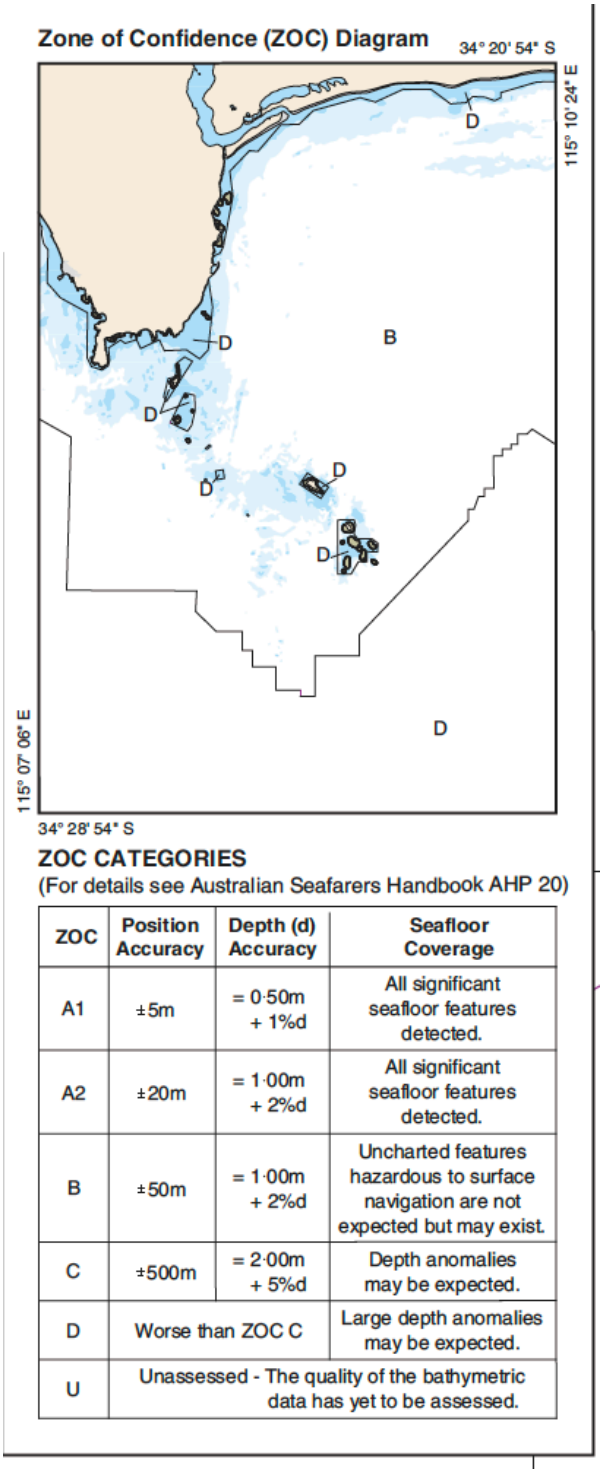
## *Software interference*

The third error source is specific to electronic charts. If you run your electronic charts on a dedicated chart plotter, this particular error will not concern you. However if you use a PC, iPad, or other computer to do your plotting, and that device has the capacity to run other software in the background, there is the possibility of the background software interfering with the plotting software. This might seem obscure, and it is quite rare, but it can have dire consequences. A well-known example is the grounding of the commercial vessel True North in the St. George Basin entrance (Kimberley) in 2004. The resulting inquiry concluded that a likely cause of the grounding was a background program interfering with the plotting software, changing the waypoints.

## *Chart survey errors*

The fourth source of error is probably the one of greatest concern to WA sailors; ***the charts are not always accurate***. This is the case regardless of whether you use charts from the Australian Hydrographic Office, the British Admiralty, Navionics, C-Map or any other supplier. The error varies from place to place and from chart to chart.

Fortunately almost all charts contain information telling you about the accuracy of the surveys used to make the chart. It is in the form of a diagram headed 'Zones of Confidence' (older charts may have a less useful 'Reliability Diagram'). An example is shown below, taken from DoT(WA) chart WA1681:




**ZOC CATEGORIES**

(For details see Australian Seafarers Handbook AHP 20)

| ZOC | Position Accuracy | Depth (d) Accuracy | Seafloor Coverage |
|---|---|---|---|
| A1 | ±5m | = 0·50m + 1%d | All significant seafloor features detected. |
| A2 | ±20m | = 1·00m + 2%d | All significant seafloor features detected. |
| B | ±50m | = 1·00m + 2%d | Uncharted features hazardous to surface navigation are not expected but may exist. |
| C | ±500m | = 2·00m + 5%d | Depth anomalies may be expected. |
| D | Worse than ZOC C | | Large depth anomalies may be expected. |
| U | Unassessed - The quality of the bathymetric data has yet to be assessed. | | |

The diagram above is for the Cape Leeuwin/Flinders Bay region and is typical of south-western WA. The chart area is divided into zones (A, B, C etc.) each with a different level of accuracy. Most of the bay is zone B (position accuracy to + or – 50m), which is a lot less accurate than your GPS. The areas where the short cuts past the Cape through the reefs lie is zoned D - accuracy worse than 500m!

## *Chart drawing errors*

Even if a chart were perfectly accurate, there is still an inherent limitation to its accuracy. This is best explained by considering a paper chart (which are the source of many, perhaps most, electronic charts). A draughtsperson has drawn the features on the chart with an ink

pen. Even if they have outstanding draughting skills, the accuracy is still limited by the thickness of the pen nib. For a typical 0.2mm drafting pen the resulting ink line is 30m thick when scaled up on a typical coastal chart of 1:150,000 (the scale used for the AUS 7-series). Even on the vary large scale DoT chart of Rottnest Island (1:25,000), a depth contour line is still 5m thick.

## Assessing errors at sea

So what practical ways are there of getting a feel for accuracy whilst you are at sea? Consider the unfortunate situation where you have to enter or leave a difficult anchorage at night. (Of course you should never put yourself in this situation, but it happens). The approach is perhaps only 50m wide, and you now know that your chart plotter might only be accurate to 100m; scary! Here are three things you can do that will help you decide if entering the anchorage is stupid, or merely difficult.

### *Reference check*

If there is a well charted object nearby with deep water next to it (e.g. a nav marker), sail up to the marker and see if the plotter shows that you are at the mark. If it does show you at the mark, that gives confidence that your GPS/plotter is quite accurate. If it shows you are off the mark, then either:

- you have an indication of how much error there is, or
- the mark is not in its charted location (happens a lot with floating marks).

### *DOP*

Look at the DOP number! If the number is high, do not rely on GPS. If the number is low, this is not an 'all-clear' message - it tells you nothing about chart datums, charting inaccuracies etc. But you have eliminated one source of uncertainty.

### *Altitude*

What has this got to do with boating? Well, your GPS doesn't just give your position on the chart; it also works out how high you are off the ground. This is of no practical use for navigating a boat, but it can give you valuable insight to the reliability of the GPS signal. If you dig down through the chart plotter menus you will probably find an altitude display. Look at it as you approach your difficult anchorage; it should be a sensible value not a ridiculous one - 50m above sea level would be a concern. Similarly, if the average altitude value is sensible but jumping around a lot ('accurate but not precise'), that should also set your internal alarm bells ringing because whatever is causing those altitude jumps might also be causing position jumps. Checking altitude is yet another tool in your accuracy toolkit.

# Conclusions

- You are fooling yourself if you think your GPS plot on a chart is consistently accurate to within less than 50m.
- Use more than just your GPS to navigate, especially if piloting through narrow spaces.
- Learn how to assess the accuracy of your GPS and charts.

# References and bibliography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