2. CHARTS

Maps which are used for marine or aeronautical navigation are called **charts**.

In Canadian waters, mariners are required to carry the latest editions of the paper charts, at the largest scale available (see section 2.2, p. 12), covering their intended course. This is in addition to whatever electronic system might be on board.

Charts must be purchased only from a Canadian Hydrographic Service (CHS) **authorized chart dealer**. Other sources may not provide the most up-to-date charts.

2.1 Chart projections

Charts are plane surfaces, in two dimensions, on which the cartographer attempts to describe portions of the Earth's surface which are in three dimensions. Distortion is inevitable, and various projections favour the preservation of either directions and angles on the surface of the Earth, or distances between points.

The main types of projections for marine charts are **Mercator**, **Polyconic**, and **Gnomonic**.

2.1.1 Mercator projections

The traditional Mercator projection is on a **vertical** cylinder tangent around the Earth at the Equator. Most marine charts use the Mercator projection system. This type of projection is prevalent for areas around the Equator, within the Tropics. It is also frequently used to represent mid-latitude areas. Its main advantage is that the parallels of latitude are horizontal lines, parallel to each other, and the meridians are vertical lines, also parallel to each other. This makes it particularly easy to read or plot latitudes and longitudes. Beyond 60° or 70° of latitude N or S, conic projections are used more often

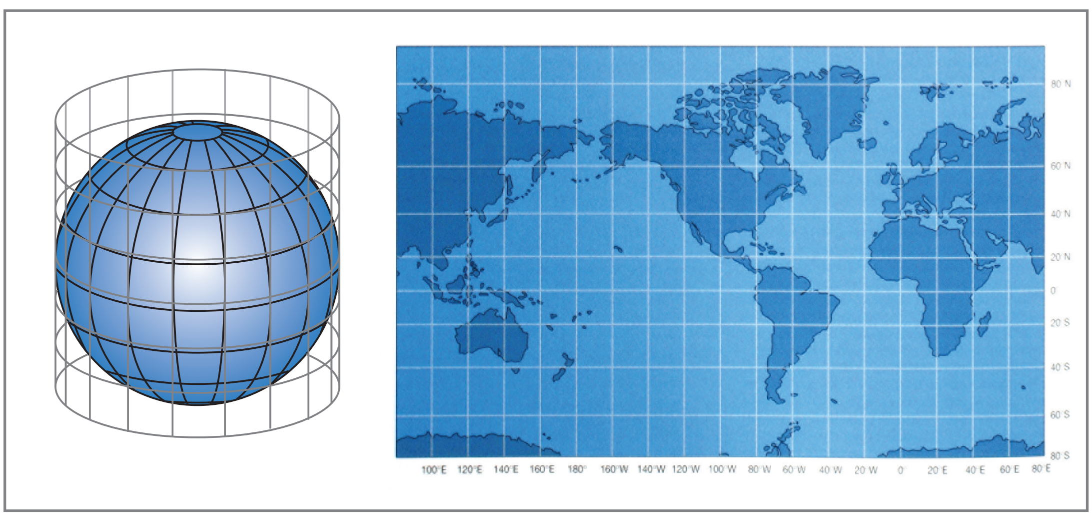


Fig. 2.1 Mercator Projections; parallels of latitude intersect meridians of longitude at 90˚. Lat and Long can be read directly on the side of the chart.

because a Mercator projection would introduce increasing distortion towards the Poles.

The less common "Transverse Mercator" projection is on a **horizontal** cylinder tangent around a Meridian (Fig. 2.2).

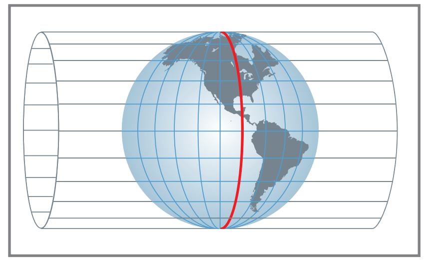


Fig. 2.2 Transverse Mercator.

On a Mercator chart representing a relatively small area, i.e. a **large scale** chart providing the most details (see section 2.2, p. 12), the angles (directions) are relatively well preserved, and so are the distances between points on the chart. Angles and distances become increasingly distorted as the scale decreases, i.e. as the chart covers larger areas.

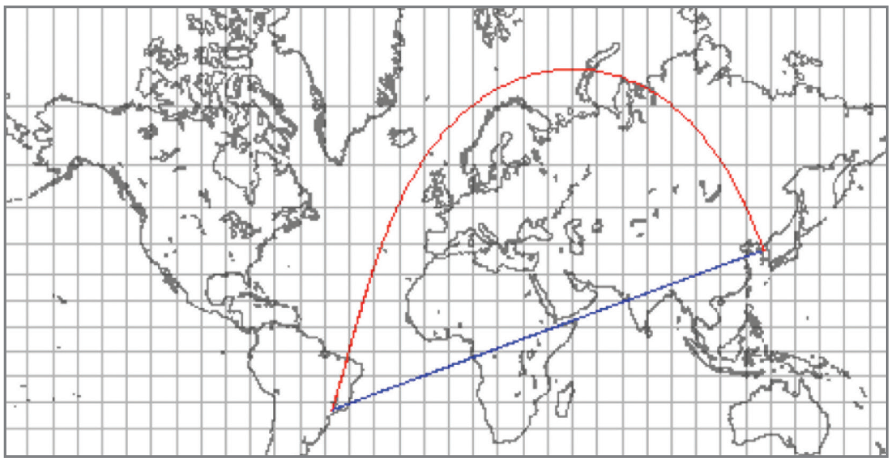


Fig. 2.3 Mercator chart: Great Circle or Geodesic line (red) vs. Loxodrom or Rhumb line (blue).

Over very large distances, a straight line drawn on a Mercator chart between two points (**Rhumb line**, in blue; Fig. 2.3) no longer represents the shortest distance between the points. A Great Circle line must be plotted (in red) point by point, from the measures of headings across each meridian, on a globe or on a Gnomonic chart (Fig. 2.6).

On the Mercator charts, the constant width between two meridians of longitude represents smaller and smaller distances on the surface of the Earth as one moves away from the equator towards the Poles. The East-West scale thus changes (increases) with latitude, which is why distances are measured with the constant scale of latitude, on the left and right sides of the charts (Chapter 5, p. 41).

2.1.2 Polyconic projections

A conic projection is made on a cone rather than a cylinder. The cone is tangent to a parallel of latitude. The parallels are displayed as curves centered on the Poles.

Conic projections are often **polyconic**, which means that several

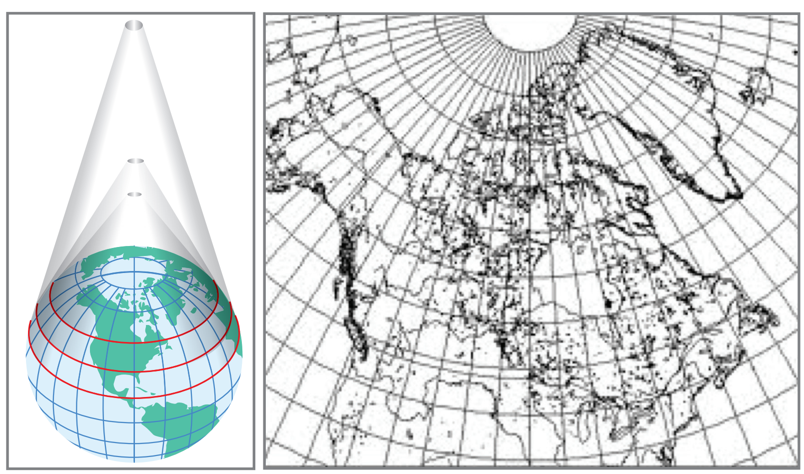


Fig. 2.4 Polyconic projections; they better maintain proportions and directions.

cones are used for each chart. This further increases the reliability of the projections: angles and distances are more reliable over greater distances. However, latitudes and longitudes are more difficult to measure, and the chart scale varies throughout the chart.

Some detailed charts of small areas, such as bays or harbours, where the preservation of angles and shapes is important for accurate positioning sights with the hand bearing compass, are made from polyconic projections (Fig. 2.5).

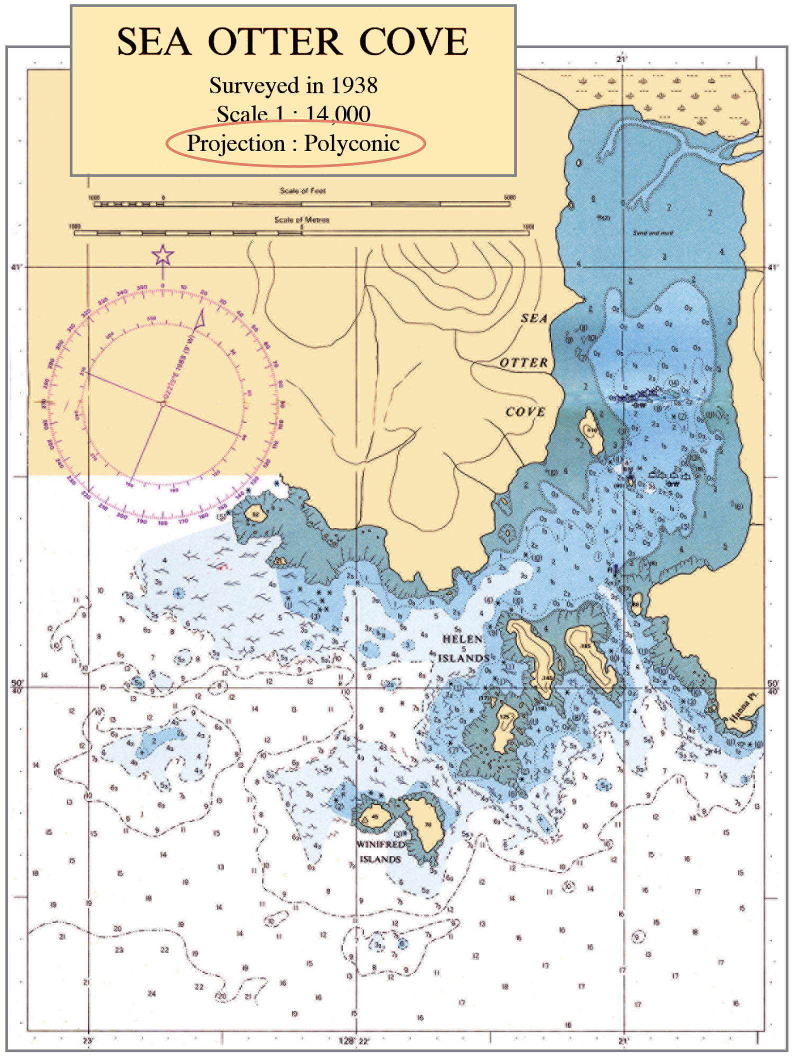


Fig. 2.5 Polyconic projections used for anchorage.

2.1.3 Gnomonic projections

Gnomonic projections are made on a flat surface tangent to the Earth at a point close to the center of the area represented (Fig. 2.6). Its main advantage is that Great Circle lines, i.e. the lines of shortest distances, are represented as straight lines. Gnomonic charts are used to plan direct routes across oceans: all Great Circles on Earth are represented by straight lines. The constantly varying headings along the route must be measured from meridian to meridian.

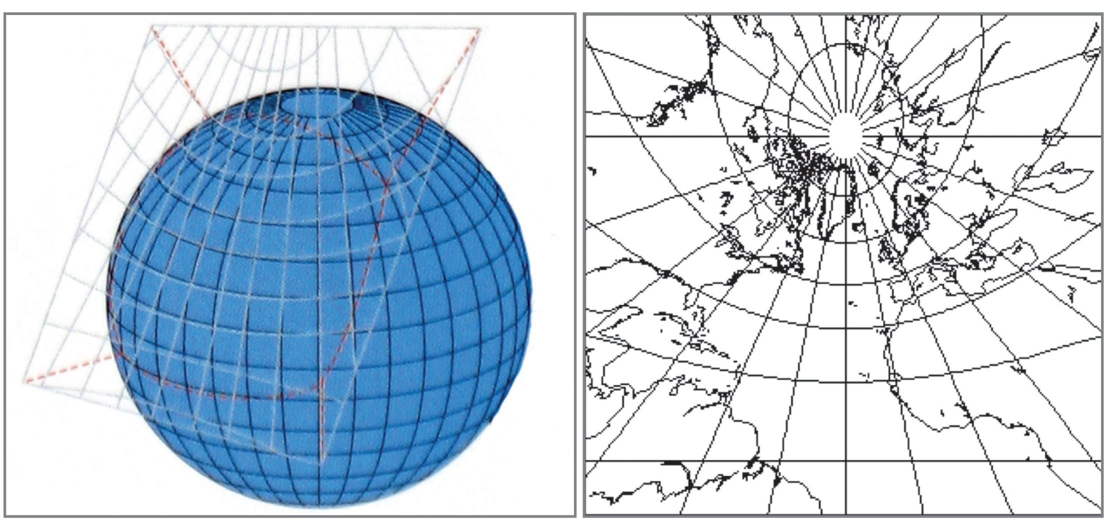


Fig. 2.6 Gnomonic projections, transforming great circle distances on the globe into straight lines on the chart.

2.2 Chart scale

The scale is the ratio of a distance between two points on the chart and the actual distance between the same points on Earth. A scale of 1/50,000 means that one cm on the chart represents 50,000 cm (500 m) on Earth.

Fig. 2.7 Chart 3001, Small Scale (1/525,000). Used for initial (overall) planning of a cruise.

Fig. 2.8 Chart 3473, Large Scale (1/12,000). Used for detailed passage planning.

A **small scale** chart makes the Earth look relatively small, with few details. Chart 3001, for instance, shows the whole of Vancouver Island, at a scale of 1/525,000 (Fig. 2.7). The fraction **1/525,000** is small, and the scale is therefore referred to as **small**. Small scale charts are used for initial (overall) planning of a cruise.

A **large scale** chart, on the other hand, makes the Earth look very large, as through a magnifying glass. Chart 3473, for instance, has a scale of 1/12,000, a much larger fraction (Fig. 2.8). Large scale charts are used for detailed passage information, for instance for transiting through Active Pass.

2.3 Transfer of points between charts

Transferring points between charts of different scales can be done in two ways:

Transfer of coordinates: The coordinates of a navigation point, such as a fix of a DR, as recorded on one chart, can be used to determine the exact location of the same point on another chart. Care must be taken that charts with different scales often use different units. For instance, the smallest units on the coordinate scales are typically 30 minutes of angle on a small scale chart, such as one covering the entire North Pacific (1/20,000,000); one minute of angle on a medium scale chart showing, for instance, the whole of Vancouver Island (1/525,000) (Fig. 2.7); down to 1/10th of a minute of angle on a large scale chart showing small areas such as the Strait of Georgia (1/80,000) or Active Pass (1/15,000) (Fig. 2.8).

Use of a landmark, bearing and distance: If the same landmark can be recognized on the two charts, then a bearing from the navigation point to the landmark can be measured on one chart and carried over to the other. Along this bearing, the distance to the landmark can be measured on the first chart with the dividers on the latitude scale, and carried over to the second chart. Here too, caution must be exercised: scales of latitudes typically vary between charts, and the distance measured on the first chart must be carefully measured again on the second chart by adjusting the dividers to the new latitude scale.

2.4 Horizontal chart datum

Until the late 1900s, each country used a different representation of the Earth: a **spheroid**, slightly flattened at its poles, and relied on specific coordinate origins to produce its own maps. The reference used to measure latitude and longitude on these maps is the country's **horizontal datum**.

Height references also varied, depending on the average elevation of the country. These different height references were equivalent to very slightly different Earth radii in each area considered, and further affected the coordinates of the points represented on the charts.

As a result of these small changes in horizontal datums from country to country, the same point on Earth had slightly different coordinates in different systems of reference, i.e. on different sets of national charts. It didn't really matter, as long as a navigator used the charts corresponding to the local reference system. In particular, a GPS had to be carefully adjusted to the specific horizontal datum used by the country publishing the charts.

A choice of some 150 horizontal datums is usually available from the GPS menu, to ensure that the coordinates given by the GPS correspond with the points of the chart. A difference of 1/10th of a minute of angle represents a distance of 150 to 200 m on the ground: the use of the wrong datum on a GPS can introduce errors of several hundred meters, up to one km or more in certain parts of the world.

The Canadian Hydrographic Services originally used the North American Datum of 1927 (NAD27) but eventually switched to the NAD 83 system, in 1983, when GPS satellites were introduced. Some Canadian charts still use the NAD 27 datum, although most are based on the NAD 83 datum, which is essentially identical to the new WGS 84 datum. The WGS 84 international system was very slightly adjusted in 1994, and again in 1997.

As the GPS system became increasingly popular, a new representation of the Earth was introduced in 1984: the **World Geodetic System of 1984** (“WGS 84”), a geocentric system which is now used internationally. Its reference meridian is 102 m East of the Greenwich Meridian because of an initial error in calibration, but all GPS units correct for this offset and provide longitudes measured exactly from the Greenwich Meridian. The default horizontal datum of new GPS units is **WGS 84**.

The impact of a change of horizontal datum is illustrated below: the Hornby light, in Australia, has two slightly different sets of coordinates under two horizontal datums: the World Geodetic Datum of 1984 (WGS-84, first line); and in the previous geodetic system, the Australian Geodetic Datum of 1966 (AGD-66, second line):

WGS-84: Lat 33° 50.014' S; Long 151° 16.860' E
AGD-66: Lat 33° 50.109' S; Long 151° 16.791' E

The horizontal datum used by the chart maker is usually noted on each chart (Fig. 2.9):

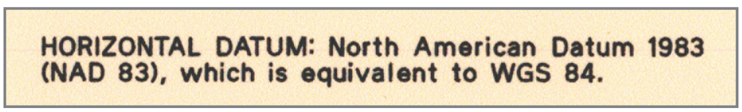


Fig. 2.9 Description of Horizontal Datum on CHS chart 3463 (Strait of Georgia). The new worldwide standard is the World Geodesic Survey (WGS) of 1984.

2.5 Vertical chart datum

While the new international GPS datum WGS 84 has both horizontal and vertical components, the vertical chart datum we are considering here is different and determines the levels of reference for measuring depth, tides and elevations. The vertical chart datum used here is specific to marine charts, and applicable to Canada only. Other countries use various reference levels for determining depths, tides, and elevations.

2.5.1 Tides and depths

! Tides and depths, in Canada, are counted from a **Vertical Datum**. The Vertical Datum, or plane of reference is defined as the **lowest normal tide**. The depths are measured below this reference plane (Fig. 2.10, top), and the tides above it.

The tides, even the very low ones, are thus almost always positive. Consequently, in Canada, the amount of water under the boat, which is the sum of the physical depth of the area (as indicated on the chart) plus the tide at that moment, is almost always bigger than the numbers shown on the chart.

The only (very rare) exceptions occur at certain times of some years when the tide is exceptionally low, typically around the Equinoxes, and can drop slightly below the reference level. The tide is then slightly negative. In 2016, not a single negative tide was recorded by any of the main stations in the Juan de Fuca Strait and Strait of Georgia on the West Coast, although the tide fell to 0.0 m in Victoria on June 12th and again on July 13th.

In contrast, tides in the US are measured from the Mean Lower Low water, i.e. the **average** of the lowest daily tides. Consequently, tides are often negative under the US system. In Seattle, for instance, out of approximately 700 Low Tides in 2016 (usually two per day), 174 were negative, meaning that, on 174 moments during the year, the depth of water below the boats was less than indicated on the chart.

Areas at the reference level (vertical datum), or slightly above, are sometimes covered (when the tide is high enough), and sometimes not; they are marked in green on the charts. Areas always covered are marked in shades of blue close to the shoreline, and white for deeper areas. (Fig. 2.11, bottom, and Fig. 2.12 - 2.15)

DEPTHS are in metres and are reduced to Chart Datum (Lowest Normal Tide), which at Tsawwassen is 3.0 metres below Mean Water Level. Depths in United States of America waters are reduced to Mean Lower Low Water.

ELEVATIONS, spot elevations and clearances are in metres above Higher High Water, Large Tide. Underlined figures on drying areas or in brackets against drying features are in metres above Chart Datum. Heights and clearances from United States of America sources are in metres above Mean High Water. Topographic contours are above Mean Sea Level at an interval of 100 metres.

Fig. 2.10 Depths (below vertical datum), Clearances and Heights, (above vertical datum). Source: Chart 3463, Strait of Georgia, Southern Portion.

2.5.2 Elevations

> **Heights (Light Houses, Towers) and clearances under a bridge or a cable, in Canada, are counted from the level of highest tide ever.** The areas above that level are never covered, and marked in yellow (Fig. 2.10, bottom, and Fig. 2.11, top).

2.5.3 Illustrations of depths and heights

The following illustrations are reproduced from *Chart 1: Symbols, Abbreviations, Terms*. They are perhaps the most important symbols for sailors, and should be well understood and memorized. Depths are counted in meters below the vertical chart datum (Fig. 2.11, lower half).

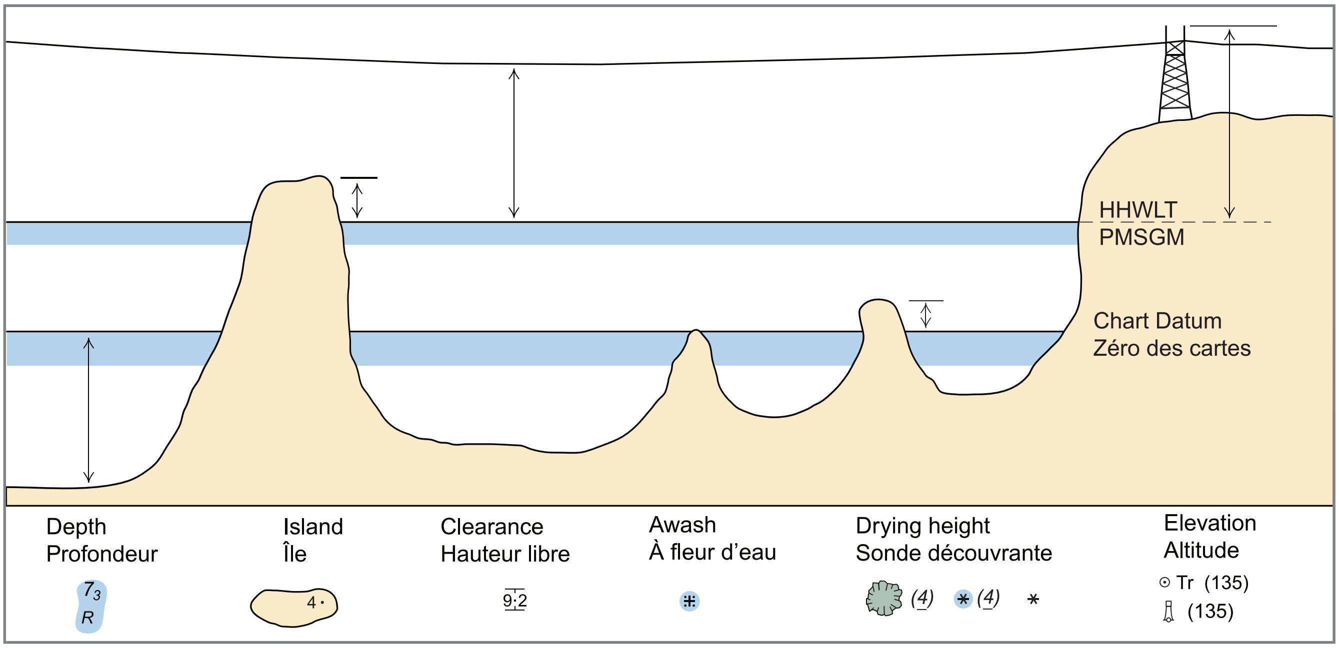


Fig. 2.11 Depths are counted down from the vertical chart datum, set as the level of the lowest normal tide. Clearances and elevations are counted up from the highest tide.

Clearances are given in meters above the highest tides ever. Regardless of the tide, there is thus always at least the indicated clearance (Fig. 2.11 top, center).

Landmark elevations, useful for determining one's distance from shore with a sextant (Chapter 15, p. 105), for example, are also counted, in Canada, above the highest tides ever. From a distance, this is the line of highest water mark along the shoreline (Fig. 2.11, top, right-hand side).

The following four figures show the representation of depths on marine charts:

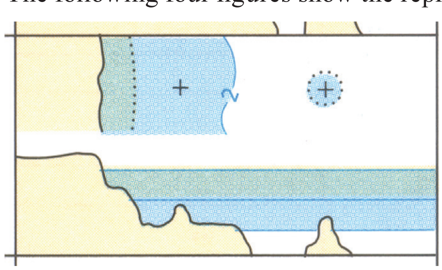


Fig. 2.12 Land which is always submerged, i.e. below the vertical datum, is indicated by various tints of blue, from darker for shallower waters to white for waters of 10 m or more. Underwater rocks of unknown depths but dangerous to surface navigation are shown as a cross without dots.

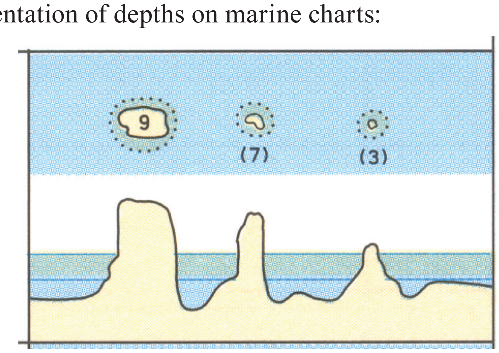


Fig. 2.13. Land which is always above water is marked in yellow. The land elevation is counted in meters above the highest water ever ("Higher High Water, Large Tides"). Here, the dry land is always at least 9 m, 7 m or 3 m above water. The brackets indicate that the numbers for the heights of the rocks are slightly out of place in order to avoid obscuring the drawing of the rock.

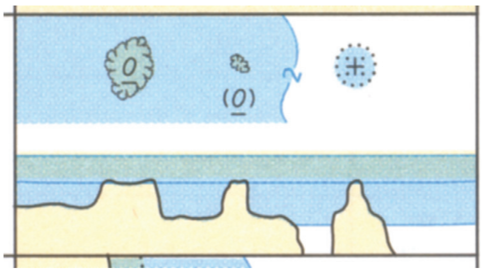


Fig. 2.14 Land exactly at datum is marked as having a height of 0 meters above datum, or, in the case of a narrow rock, as a cross with four dots. Here again, brackets indicate heights slightly out of position.

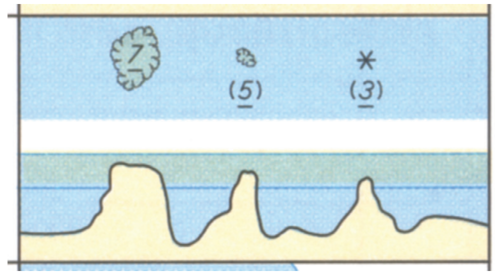


Fig. 2.15 Land which is sometimes visible above water but is sometimes submerged, depending on the tide, is marked in green (for weeds and barnacles). The horizontal line under the number representing the height in meters is a reminder that the number is not a depth, but a HEIGHT ABOVE DATUM. Whether the rocks, or the bottom surface, are visible depends on the tide. Here, the three rocks are 7 m, 5 m and 3 m above the vertical datum, and can therefore only be seen when the tide is less than 7 m, 5 m and 3 m respectively.

2.6 Chart information

The characteristics of each chart, and information about its data, are given in the chart margins and in the information box inside the chart. Knowing the country of manufacture of a chart is essential to set the GPS horizontal datum.

The following figures illustrate the representation of chart information:

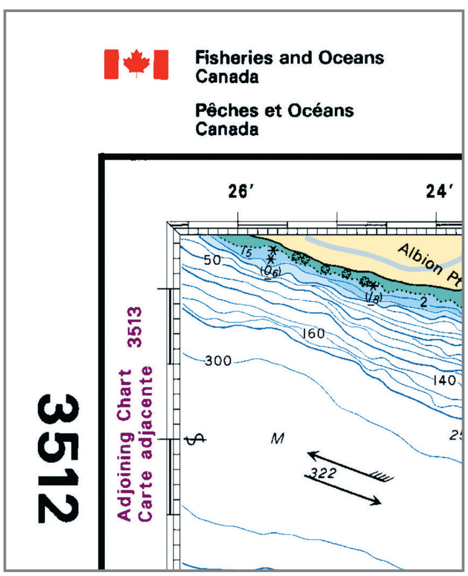


Fig. 2.16 Chart number; Issuer.

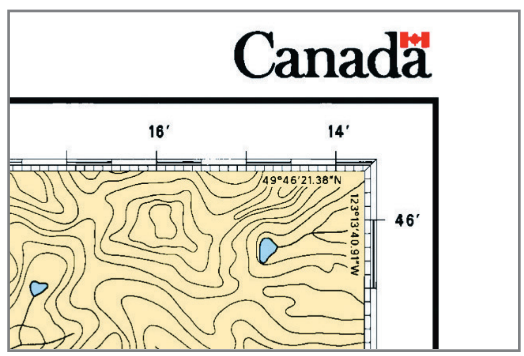


Fig. 2.17 Country of manufacture.

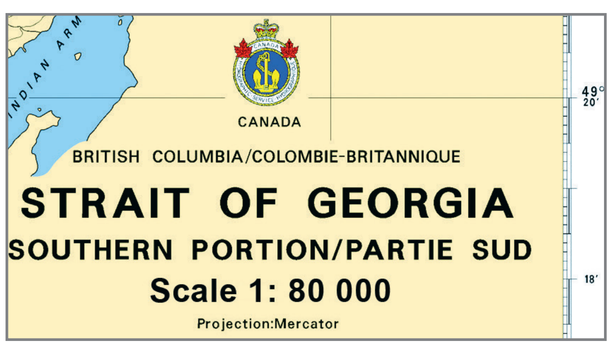
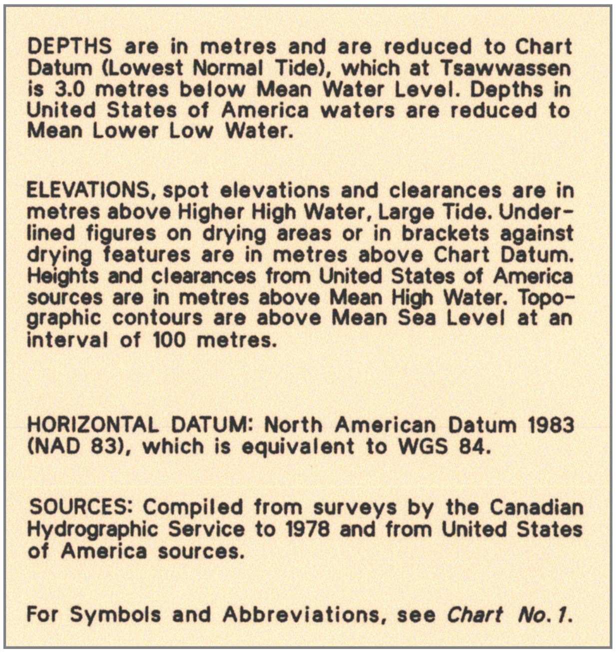


Fig. 2.18 Chart title and scale.


DEPTHS are in metres and are reduced to Chart Datum (Lowest Normal Tide), which at Tsawwassen is 3.0 metres below Mean Water Level. Depths in United States of America waters are reduced to Mean Lower Low Water.

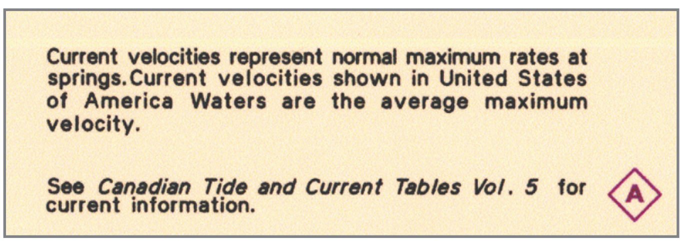
ELEVATIONS, spot elevations and clearances are in metres above Higher High Water, Large Tide. Underlined figures on drying areas or in brackets against drying features are in metres above Chart Datum. Heights and clearances from United States of America sources are in metres above Mean High Water. Topographic contours are above Mean Sea Level at an interval of 100 metres.

HORIZONTAL DATUM: North American Datum 1983 (NAD 83), which is equivalent to WGS 84.

SOURCES: Compiled from surveys by the Canadian Hydrographic Service to 1978 and from United States of America sources.

For Symbols and Abbreviations, see *Chart No. 1*.

Fig. 2.19 Vertical datum (depths and tides), and Horizontal datum (GPS). Source: Chart 3463, Strait of Georgia, Southern Portion.


Current velocities represent normal maximum rates at springs. Current velocities shown in United States of America Waters are the average maximum velocity.

See *Canadian Tide and Current Tables Vol. 5* for current information.

A

Fig. 2.20 Source of further information for the currents in passes.

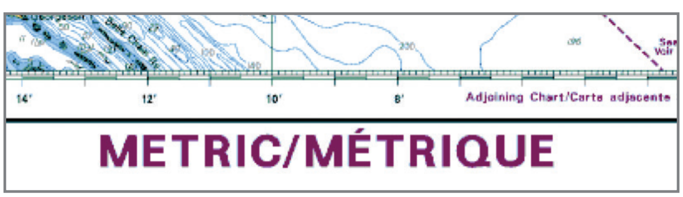
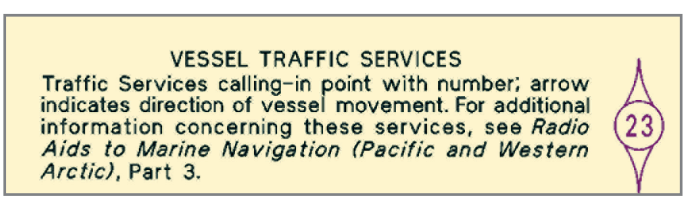


Fig. 2.21 Most Canadian charts are metric, but not all, yet.


VESSEL TRAFFIC SERVICES

Traffic Services calling-in point with number; arrow indicates direction of vessel movement. For additional information concerning these services, see *Radio Aids to Marine Navigation (Pacific and Western Arctic)*, Part 3.

23

Fig. 2.22 Compulsory radio reporting point No. 23 for boats sailing under the Vessel Traffic Services.

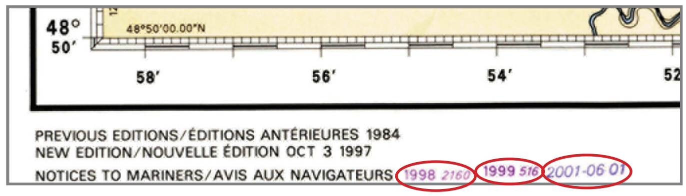


Fig. 2.23 Dates of amendments since the original printing, incorporated on the chart (stamped in colour, bottom right of the chart).

1' of Latitude = 1 NM
DO NOT use the scale of longitudes to measure distances!

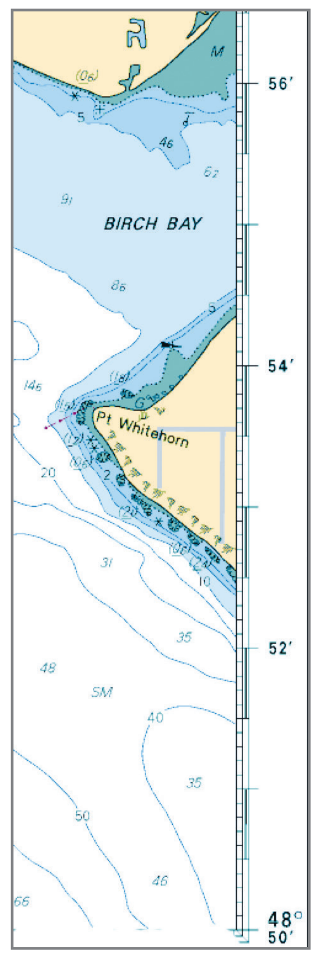


Fig. 2.24 Scale of latitudes, right or left sides of the chart. Use this scale to measure distances.

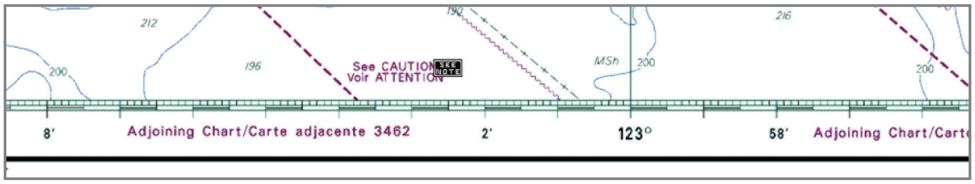


Fig. 2.25 Scale of longitudes, top or bottom edges of the chart.

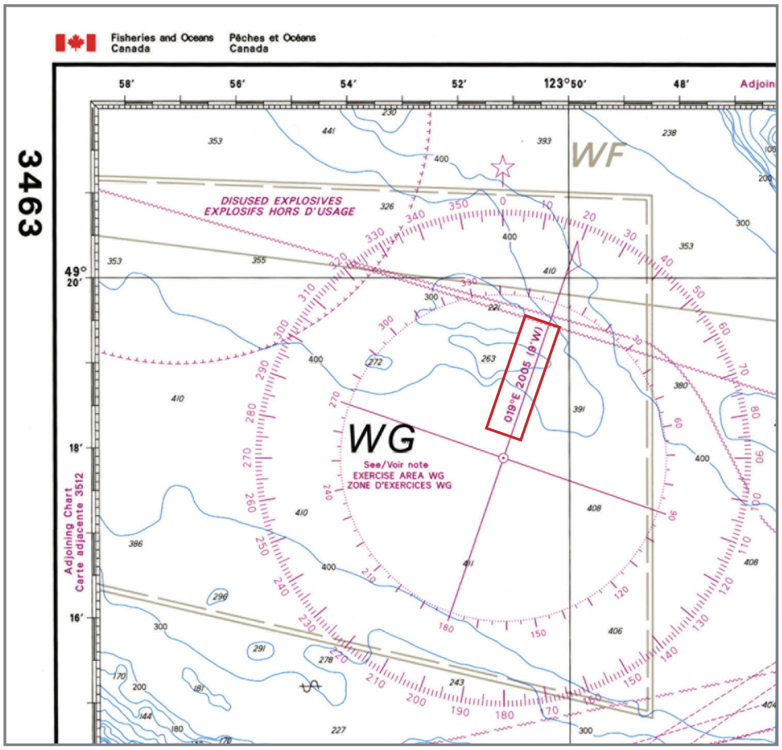


Fig. 2.26 Compass rose drawn over the military restricted zone **WG** outlined in light grey.

Fig. 2.27 Typical characteristics of the Magnetic Variation as given on the chart's compass rose. In 2005, Magnetic Variation, in this area, was 19º East, decreasing by 9' every year (extracted from Fig. 2.26).

On the radius of the compass rose pointing to Magnetic North, the annual change of magnetic variation (9' towards the west) is indicated, following the latest measure of the variation (19° E) shown on this chart, taken in 2005 (Fig. 2.26 and Fig. 2.27).

The current (2016) magnetic variation in the Vancouver area is 17° E, still decreasing at the rate of 9' per year.

"Insets" are small but interesting areas of the charts, magnified in separate windows, usually on land.

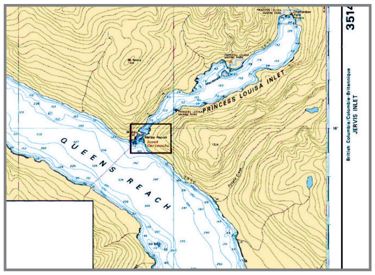


Fig. 2.28 Inset for Malibu Rapids on chart 3514 (Jervis Inlet), at the center of this area of the chart.

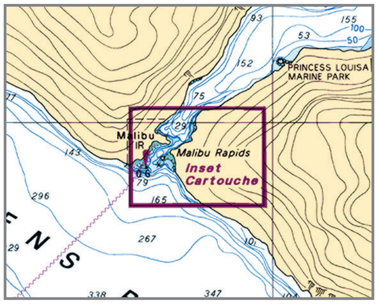


Fig. 2.29 Same area of the same chart, magnified to better show the inset.

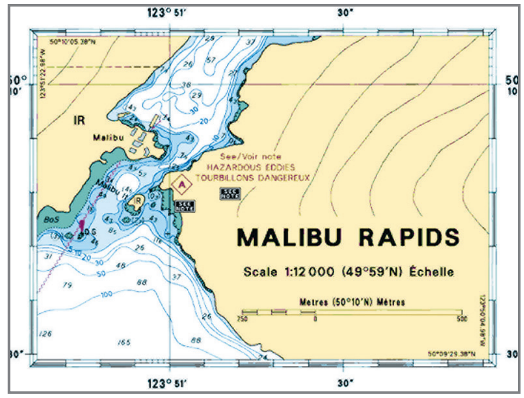
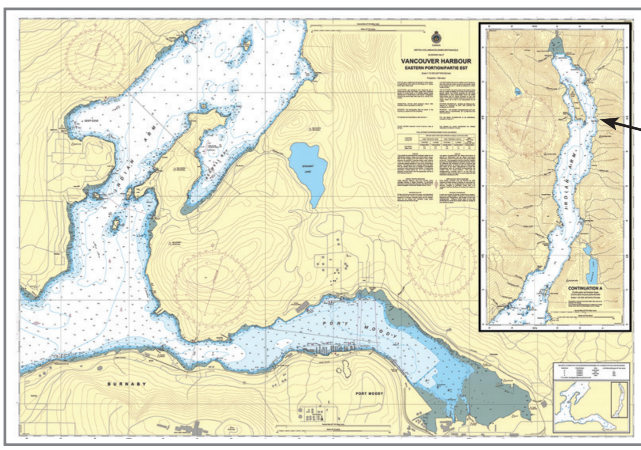


Fig. 2.30 The inset itself, as shown on another area of the chart.

"Continuations" are areas which fall outside of the chart, like the head of an inlet, but are shown in a separate window, usually on land (Fig. 2.31 and 2.32). The scale might be different.



Continuation of Indian Arm, showing the rest of its northern end, at a smaller scale.

Fig. 2.31 Indian Arm. Note that the northern end of the arm is missing (see its **continuation**).

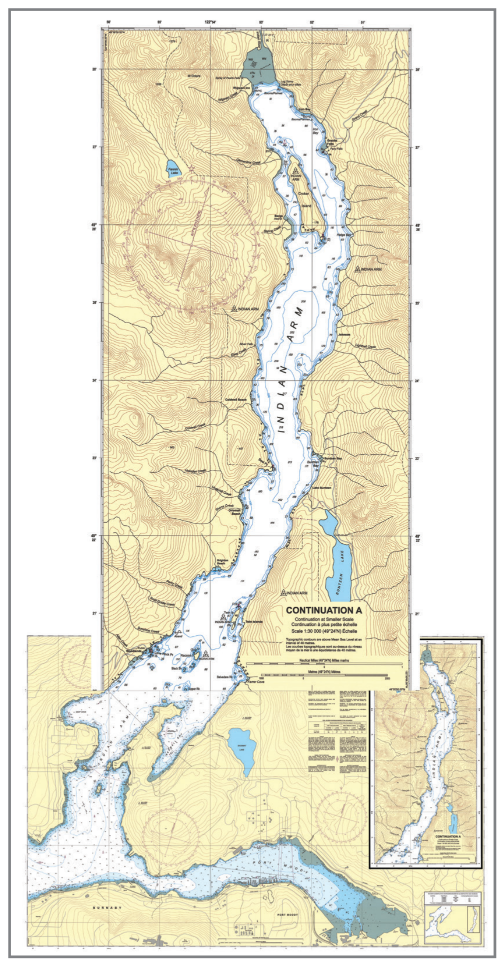


Fig. 2.32 Indian Arm with its continuation brought back to its proper place.

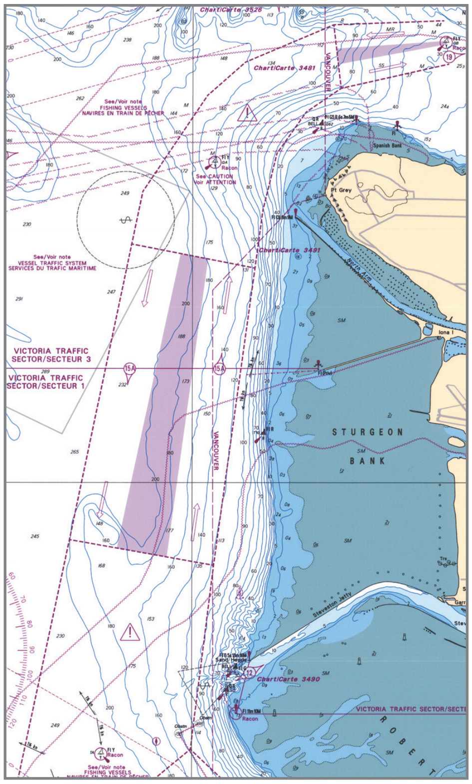


Fig. 2.33 Traffic Zones; Traffic Separation Zones. Commercial ships within the traffic zones keep the separation zone to their port, as cars do along a highway.

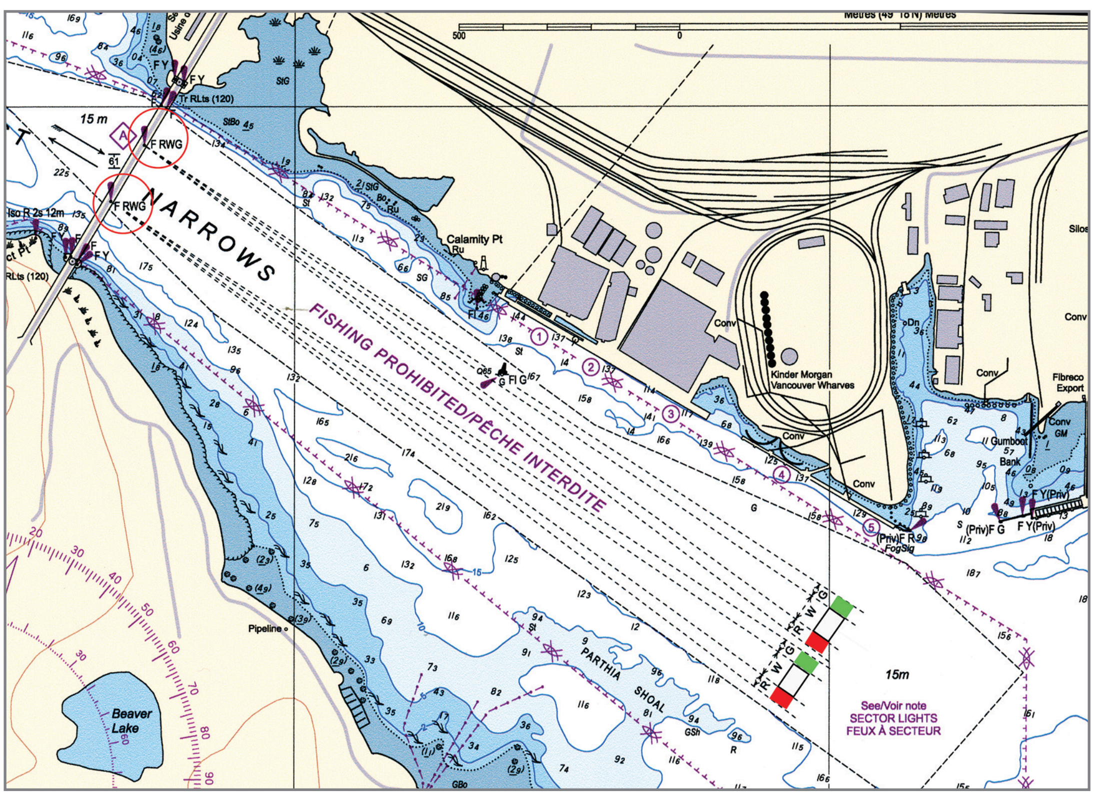


Fig. 2.34 Sector Lights at the entrance (exit) of Vancouver Harbour.

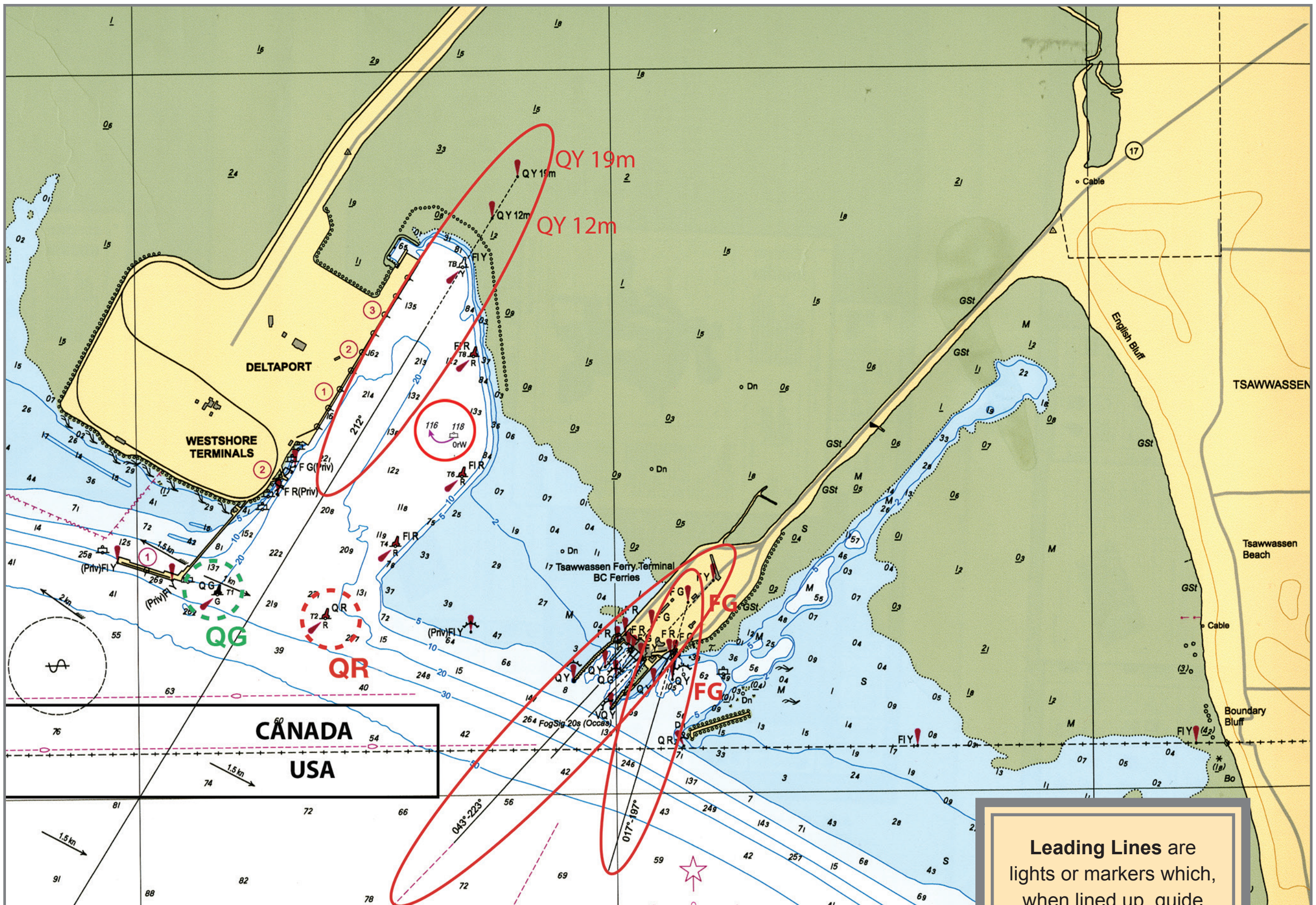


Fig. 2.35 Look for: Three Leading Lights (ellipses); one Buoy Symbol out of position Delta Port (circle); one National Border (Canada-US). Note also the Quick Green light to port at the entrance of Delta Port, and the Quick Red light to starboard.

Leading Lines are lights or markers which, when lined up, guide boats through narrow passes.

2.7 Chart symbols

The chart symbols are described in detail in *Chart 1, Symbols, Abbreviation, Terms* published by the Canadian Hydrographic Service.

An extract of some of the most common symbols is given below (Fig. 2.36):

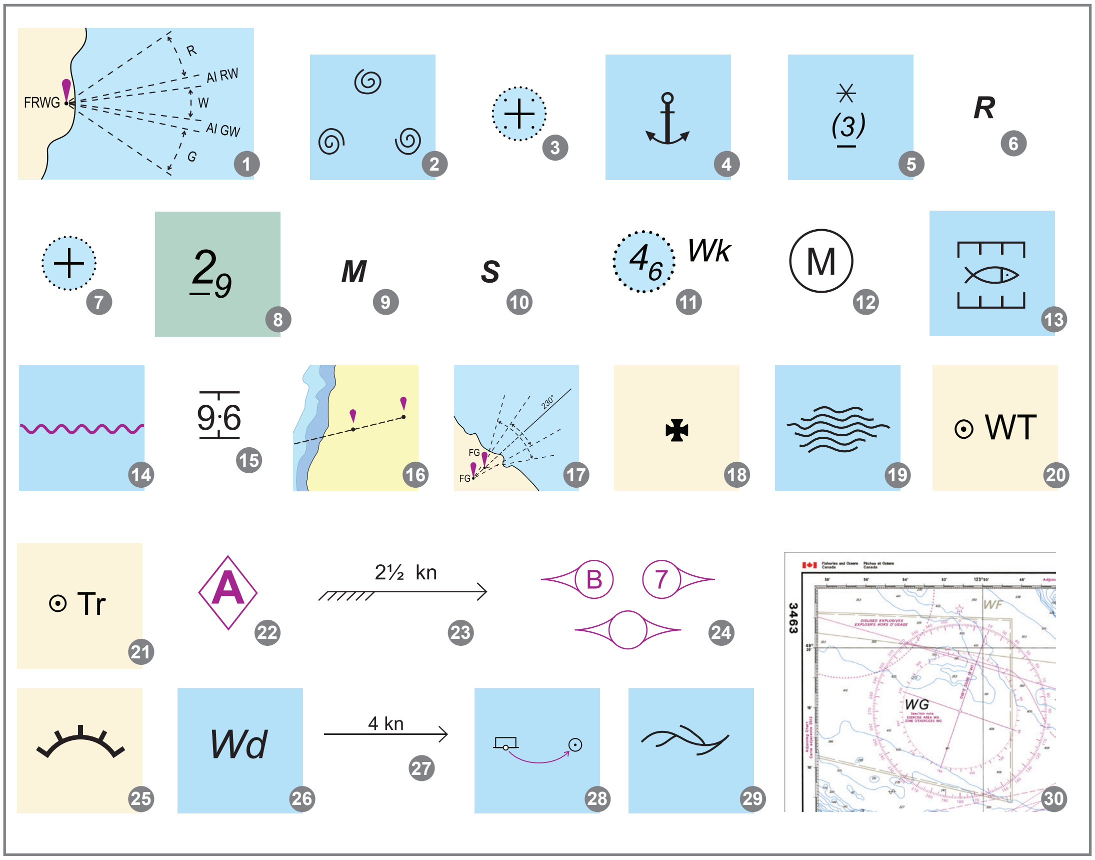


Fig. 2.36 Main chart symbols.

1. Sector Lights, identified with fixed lights (“**F**” by the light) visible, in each sector, in the colours Red, White or Green. Within the narrow separating sectors, the navigator sees the light as alternating (“Al”) between Red and White in the sector North of the White, and Green and White in the sector South of it.

2. Eddies

3. Rock “awash at datum”, i.e. exactly at vertical datum. In Canada, it is at the level of the lowest normal tide. Note the four dots.

4. Anchorage

5. Rock, 3 m above datum (the datum is represented by the underline); The height number is a little out of place, hence the parentheses: the number 3 (for 3 m) should be printed exactly on top of the star marking the rock, but this would not be practical.

6. Rock bottom
7. Underwater rock of unknown depth, dangerous to surface navigation.
8. In an area which covers and uncovers (green), bottom 2.9 m above datum (underline). Some tides are obviously higher than 2.9 m (as noted by the green colour).
9. Mud bottom
10. Sand bottom
11. Wreck; highest point at a depth of 4.6 m below datum
12. Marina
13. Marine farm
14. Submarine cable
15. Vertical clearance under a cable or a bridge, measured from the reference plane for elevations, i.e. The highest tide ever. Here: 9.6 m.
16. Leading line
17. Leading light, with sector lights on each side
18. Church
19. Overfalls, tide rips, races
20. Water tower
21. Tower
22. Tidal stream diamond: "Position of tabulated tidal stream data with designation" which means that further information on the current in the area is given on the chart, in the Information section.
23. Direction of flood (barbs) current, with speed
24. Compulsory Radio reporting points vessels under Vessel Traffic Services
25. Radar reflector; displays large marks on the radar screen
26. Weed bottom
27. Direction of ebb (no barbs) current, with speed
28. Buoy symbol printed slightly out of place. Exact location is where small circle is shown (on older charts only).
29. Kelp
30. The area outlined in light grey, entitled WG (Whiskey Golf), is a military exercise zone. Keep out when zone active, as broadcast on the marine-weather channels.