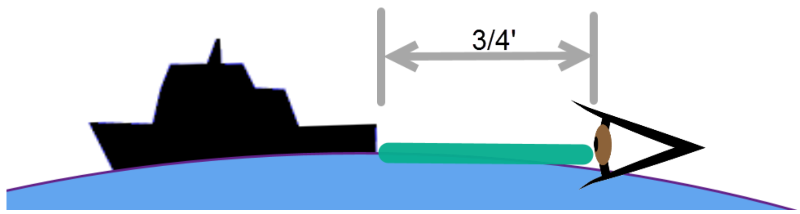
Distance to the horizon – you can't see forever

By Capt. Geoff

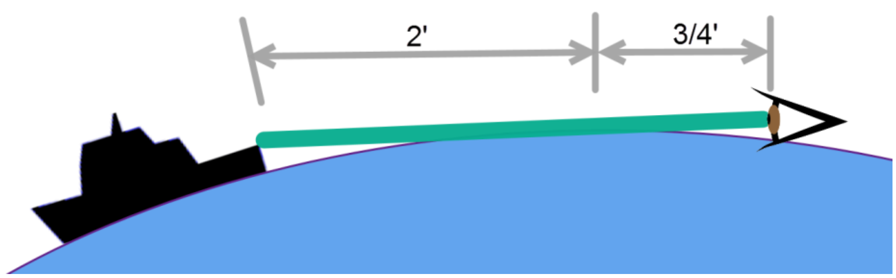
Almost everyone has seen or read of ships disappearing over the horizon.

In some cases, a vessel moving away from you can actually appear to be sinking, particularly if, for example you were swimming, so your eyes are close to the surface of the water.

The phenomenon is caused by curvature of the earth. The two primary factors are the height (above the water) of the observer and the height (again above the water) of the object. If you are swimming, with your chin just touching the water, your "height of eye" would be about 4 inches (10 cm). Distance to the horizon all around you would be about ¾ of a nautical mile. Anything at water level beyond this range, say the boot topping at the waterline of a boat, would no longer be visible.



As you watched the boat head away, it would appear to continue to get lower in the water. At about 2¾ nautical miles, everything below the gunnel (assuming it is 3 feet [~1m] above the water) would no longer be visible. This distance is a combination of the swimmer's visible horizon, and the visible horizon from the boat's gunnel (the distance to the horizon if you were aboard the boat, with your eye level with the gunnel).



> The second graphic can be a bit misleading, as the boat is rotated to be parallel with the curved water surface. It appears that most of the cabin would also be below the swimmer's line of sight. This is only because I have exaggerated the curve of the earth and drawn the vessel very large to make it more visible. In the real world, anything above the gunnel (assuming it is the same height all around the vessel) would be visible at that range.

For generations, mariners have taken advantage of this principle to determine the range of an object based on how much of it they could see. To measure the distance to a ship that was "hull down" (like our example above when everything below the gunnel is no longer visible), the distance to the visual horizon for height of eye of the observer (whether from the deck or masthead) was added to the distance to the visual horizon of the probable height of the gunnel of the observed ship to get a good estimate of the distance to that vessel.

Before accurate timepieces, unless they did extensive calculations such as lunars, offshore navigators could precisely determine only their Latitude. They did this by observing the angle of the sun above the horizon at their local noon, and correcting for dip (a related, but separate, discussion) and the date. (Similar calculations could be done using stars and planets.) They would log their course and speed during the voyage to estimate their current position, but any unknown current would affect the accuracy over the days or weeks that they were out of sight of land. To safely close the land they would choose a landfall that was tall, distinctive and near coastline that runs North/South, with deep water until close to shore. The height and position of that landfall would be known, so as they neared the coast they would sail North or South to the latitude of the landfall, then "run their Easting (or Westing) down", until they sighted it. When they "raised" their landfall, they would know how far they were from it, because they already knew its height, and their own height of eye. A 3,000 ft. (914 metre) peak could be visible for more than 64 miles offshore (plus distance from your height of eye), giving them adequate warning of the proximity of land. Combined with a bearing of the object, they would finally be able to fix their position fairly accurately.

One of the more famous European landfalls is Ushant, memorialized in the sea shanty "Spanish Ladies". The lighthouse, Phare du Créac'h, has a light that was considered the most powerful in the world. It is at an elevation of 70 m (230 ft), so it would be visible at over 17 nautical miles (plus distance from your height of eye). Because of the light, ships could raise it, day or night, far enough offshore so as to be able to confirm their position while still clear of the rocks.

Technically, when measuring the elevation of something ashore while aboard a vessel, you should take into account the tide height when measuring the height of the object. Charted elevations of objects are measured above a standardized high water mark. If you look at the title block of charts that cover the Campbell River area, such as Chart 3539, you will see that elevations are based on Higher High Water, Large Tide (HHW, LT). For Campbell River itself, the table in the title block advertises this as 4.8 metres. So at a "zero tide" (Chart datum), the elevation of the shore object, is effectively increased by that amount when observed from sea level. However, for higher elevation objects, the percentage of height from tidal range versus elevation is fairly small, so won't affect your dipping height by much. For lower elevation objects, the difference is more significant. I'd suggest calculating the visible horizon at low and high water for these objects to see what difference it makes.

A point of interest on at least some BC charts (and possibly others) is that inland elevations come from BC Provincial data. Provincial data uses Mean Sea level as its basis (this is the reason for the second last sentence in the Elevations paragraph in the title block of 3539). But given the ranges we are working with when using mountain tops, the correction is negligible.

However, charted elevations for objects such as marine aids to navigation, clearances for overhead wires, etc. definitely use Higher High Water, Large Tide in BC tidal waters (for other areas, check your chart).

Of course large waves will affect any attempt to use this system. And finally, atmospheric haze or refraction can throw everything off.

The same principle can be used to determine the maximum range that radar might pick up a target. The difference between what you can see and what your radar can see is not that significant. A lot of the difference is that the height of eye becomes the height of radar scanner. On the other hand the return from the top of the mast of the sailboat you are trying to spot is a lot less than the return from its hull.

For using the formula with radar, the 1.17 factor for feet is replaced by 1.22 (and the 2.11 factor for metres is replaced by 2.21). Before electronic positioning aids became common, we used the formula to determine how far away we could expect to pick up a mountain top on radar while crossing Hecate Straits. Radar scanner height, transmitting power, wavelength and tuning will affect the theoretical maximum, but it provides a starting point. The farthest I ever used it was as 3rd mate on a Weather ship. Coming in after seven weeks at sea, using mainly Loran A for navigation, a radar return from a mountain top was a welcome sight. Our radars were very powerful and the scanners were mounted about 65ft up (about 20ft higher than height of eye from the bridge). We spotted one mountain top at over 80 miles.

There are a number of different formulas that can be used to calculate the distance to the horizon. For this article and the table on the last page, I am using the simplified one from Bowditch (link to Bowditch on our website). Also note that in the article, I rounded some of the numbers to aid readability.

Caution: With GPS providing a position with accuracy of a few metres or less, people are used to thinking that other methods provide the same level of accuracy. As noted above a number of factors affect the accuracy of determining the visible horizon, and results are normally rounded to the nearest tenth of a mile under the best of conditions. Do not expect precise results from this method.

The Campbell River area is a great area to cruise, with hundreds of miles of channels and many inlets and bays to explore. But there are many rocks and other hazards, so knowing how to navigate (among other things) is critical. To learn more about how to safely navigate our area, consider taking our boating course. For more details, please visit our website at http://www.ripplerocksquadron.com

Distance to Visible Horizon (nautical miles) – see accuracy caution in article

To use: Add distance to visible horizon for your height of eye + distance to visible horizon of object (need to add tidal factor [elevation baseline – tide height] if object is ashore for more accurate results).

$1.17\sqrt{Height\ of\ eye\ (\boldsymbol{feet})}$

Height	Horizon	Height	Horizon
1	1.2	1,500	45.3
2	1.7	1,600	46.8
3	2.0	1,700	48.2
4	2.3	1,800	49.6
5	2.6	1,900	51.0
6	2.9	2,000	52.3
7	3.1	2,100	53.6
8	3.3	2,200	54.9
9	3.5	2,300	56.1
10	3.7	2,400	57.3
20	5.2	2,500	58.5
30	6.4	2,600	59.7
40	7.4	2,700	60.8
50	8.3	2,800	61.9
60	9.1	2,900	63.0
70	9.8	3,000	64.1
80	10.5	3,100	65.1
90	11.1	3,200	66.2
100	11.7	3,500	69.2
200	16.5	4,000	74.0
300	20.3	4,500	78.5
400	23.4	5,000	82.7
500	26.2	5,500	86.8
600	28.7	6,000	90.6
700	31.0	6,500	94.3
800	33.1	7,000	97.9
900	35.1	7,500	101.3
1,000	37.0	8,000	104.6
1,100	38.8	8,500	107.9
1,200	40.5	9,000	111.0
1,300	42.2	9,500	114.0
1,400	43.8	10,000	117.0

$2.11\sqrt{Height\ of\ eye\ (\boldsymbol{metres})}$

Height	Horizon	Height	Horizon
0.5	1.5	100	21.1
1.0	2.1	150	25.8
1.5	2.6	200	29.8
2.0	3.0	250	33.4
2.5	3.3	300	36.5
3.0	3.7	350	39.5
3.5	3.9	400	42.2
4.0	4.2	450	44.8
4.5	4.5	500	47.2
5.0	4.7	600	51.7
5.5	4.9	700	55.8
6.0	5.2	800	59.7
6.5	5.4	900	63.3
7.0	5.6	1,000	66.7
8.0	6.0	1,100	70.0
9.0	6.3	1,200	73.1
10	6.7	1,300	76.1
12	7.3	1,400	78.9
14	7.9	1,500	81.7
16	8.4	1,600	84.4
18	9.0	1,700	87.0
20	9.4	1,800	89.5
25	10.6	1,900	92.0
30	11.6	2,000	94.4
35	12.5	2,100	96.7
40	13.3	2,200	99.0
45	14.2	2,300	101.2
50	14.9	2,400	103.4
60	16.3	2,500	105.5
70	17.7	2,600	107.6
80	18.9	2,700	109.6
90	20.0	2,800	111.7

Formula and tables have been checked against other sources, but use at your own risk