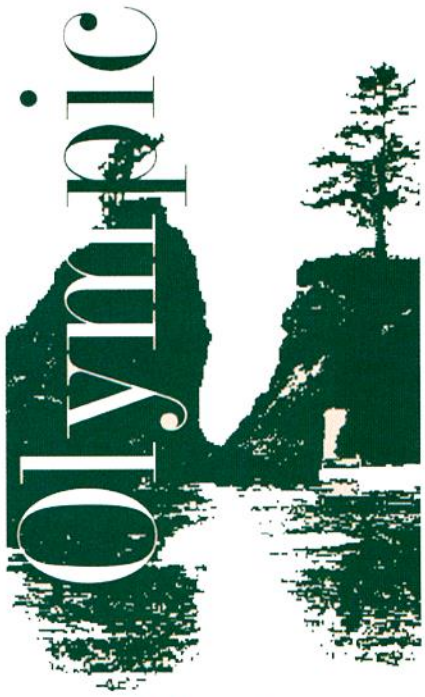
Determining Line of Sight Distances

Shoreline to Offshore Power Generation Facilities

UNIVERSITY OF WASHINGTON



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Primary Objective

Determine the distance at which an offshore facility is obscured by the horizon line from the perspective of an observer on the shoreline. Provide maps that accurately and informatively depict the viewshed extent along the Outer Washington Coast for given observer and facility heights.

Determinants

Shoreline

The shoreline used for this task was a shoreline provided by Olympic Natural Resources Center (ONRC) to the Washington Department of Natural Resources (WaDNR) as one of the deliverables for the Marine Spatial Planning work completed in 2013. This line was clipped at a point a few miles west of the northernmost point along the Outer Washington Coast and approximately one mile south of the north jetty on the Washington State side of the Columbia River. Shorelines inside the jetties at the entrances of the major estuaries along the coast were also removed.

Area of Interest

The area of interest is a longitudinal line drawn from the northern endpoint of the MSP shoreline described above to the northern boundary of the United States and follows that boundary eastward to a line 100 kilometers (~ 61 Miles) offshore of the shoreline providing the eastern boundary. At the southern end, a latitude line extends from along the southern edge of the Washington State Three Mile Limit out to the eastern boundary just described. Any viewshed generated would be clipped to the boundaries of this AOI.

Observer

The observer heights chosen are as follows, all of which were converted to meters for the distance calculations below:

1. Six feet; an observer of average height standing on the shoreline
2. Twenty five feet; an observer in a two story structure on the shoreline
3. Thirty five feet; an observer in a three story structure on the shoreline

Power Generation Facility

Facility heights were chosen to represent:

1. Ten meters; a typical height for a wave generator
2. Ninety meters; the hub height of a large wind turbine
3. One hundred twenty meters; the maximum height the blades of a large wind turbine might extend

Horizon Distance

The horizon can be considered to be the point of intersection of the arc of the Earth's surface and the line of sight distance at which an offshore facility is obscured by the horizon line from the perspective of an observer on the shoreline. This line has two components which are summed together:

1. The distance the horizon is from the observer at a given height
2. The distance the horizon is from the facility of a given height

There are very precise formulas for determining these distances. However, due to significant changes in the atmospheric environment which would affect the actual distances, a simpler formula was chosen, which, under the circumstances, is much more appropriate for this task. The two most important changes are atmospheric humidity and turbulence, almost a constant presence over Eastern Pacific waters off our shore and can vary significantly, effectively "blurring" any effort to obtain this distance in a determinate way.

Thus, a more appropriate strategy to account for this is to use a constant in the calculations that account for the consequent refraction and greater distance at which a facility might be seen. Therefore, the "humid air" distance represents the average approximate distance from shore required to keep facilities hidden over the horizon. In general, humidity and turbulence add approximately 8% to the LOS distance.

LOS Distance Formulation

The formula used for this task was $d = k\sqrt{h}$ where h is height in meters, and d is distance in kilometers.

The constant, k is 3.57 for dry air and 3.86 for humid, turbulent air (see https://en.wikipedia.org/wiki/Horizon).

Thus, the dry air formulation would be $d(km) = 3.57\sqrt{h(m)}$ and for humid air it would be $d(km) = 3.86\sqrt{h(m)}$

Because the LOS distance would be composed of the sum of the distance to the horizon of both the observer and the facility, this formulation needs to be used:

1. Dry air:
   $d_{LOS} = d_{observer} + d_{facility}$; $d_{LOS} = 3.57\sqrt{h_{observer}} + 3.57\sqrt{h_{facility}}$; $d_{LOS} = 3.57(\sqrt{h_{observer}} + \sqrt{h_{facility}})$
   where d is in kilometers and h is in meters.
2. Humid air:
   $k = 3.86$; $d_{LOS} = 3.86(\sqrt{h_{observer}} + \sqrt{h_{facility}})$ where d is in kilometers and h is in meters.

The distance, d_{LOS}, will be used to perform the GIS operations to generate the viewsheds displayed on the maps.

GIS Processing

Once d_{LOS} has been determined, the MSP shoreline described above is buffered to that distance, using the geodetic buffer option, creating a buffer polygon around the MSP shoreline. A polygon shapefile that was created using the boundaries of the AOI was then used to remove the portion of the polygon buffer created that lie outside the AOI. This new polygon is a representation of the viewshed of interest and was saved to the workspace as a product.

The viewsheds were saved as datasets; one for a 6 foot observer, consisting of one each for the dry air and humid air 120 meter facility height, one for the humid air 90 meter facility height, and one representing the humid air 10 meter facility height. In the same manner, a 25 foot and a 35 foot observer height dataset were also created.