Tsunami Travel Time Approximation

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1) On June 19, 2004, a 400 m diameter asteroid subsequently named 2004MN4 (Apophis) was discovered. What makes this asteroid somewhat unusual is that it is on a path to pass close by Earth in 2029, with a return to near-Earth orbit in 2036. Initial tracking data suggested an ~3% chance that this asteroid would strike the Earth in 2029, and while subsequent tracking has eliminated this possibility the asteroid will pass close enough to us that the nature of the orbital perturbation is difficult to predict; this is problematic as the asteroid will return for a second near-Earth pass in 2036, raising the (likely small) possibility that a direct hit could occur. As a result, considerable effort has been made to understand the consequences of a hit from Apophis, with a tsunami in Earth's single largest target—the Pacific Ocean—as the focus of many studies. Tsunamis have such long wavelengths that, even in the deep ocean, they can be treated to first order as a shallow wave phenomenon. Their velocity at any given spot is thus given by $v = \sqrt{dg}$, where d is local ocean depth in meters and $g = 9.8$ m s^{-2}.

   Starting with a topography/bathymetry map of the Pacific Ocean (in an Azimuthal Equidistant projection that preserves distance and direction) and a proposed location for the 'ground zero' location, your task for this problem—which should tap into your GIS skills and requires some technical ingenuity—is to:

   a) Generate a tsunami velocity map (raster) for the water bodies in the map area, symbolized intelligently to help a user understand the variations that occur in the Pacific. This map should depict the velocity a wave travels at any given point on the map. (*10 pts*)

   b) For six major cities (Los Angeles, Tokyo, Seward, Honolulu, Auckland, Conception) around the Pacific rim, construct an **alphabetically arranged table** that reports (*25 pts*):

      i) The shortest distance between the impact site and the city (show these lines on the map, and label them with the city names);

      ii) Mean tsunami wave velocity along each line [**Hint**: explore the use of **Zonal Statistics**, this is not a problem you should solve with a Cost Distance method]; and,

      iii) Calculate the time (in hours) required for the tsunami to reach each city.

   c) Compare your results for Seward and Los Angeles with those from a significantly more complex calculation, which can be viewed at a web site online. Go to http://es.ucsc.edu/~ward/movies_main_index.htm and from there select the Impact Tsunami movies and then the movie for Asteroid 2004MN4 (Pacific); the time elapsed will show in the upper right hand corner in a yellow rectangle. Assess the patterns you observe, and ***after doing some careful independent research*** thoughtfully postulate some sensible reasons, in defensible detail, why your answer might be different. (*15 pts*)

   Your product for this question should include a single-page map that illustrates the information from 1a and 1b (including the table); a detailed bulleted list describing how you produced the velocity map for 1a and obtained your answers to 1b; and finally an ~1 page answer for 1c.