Estimation of the required height of seawall for protection from Tsunami.

Sergey V. Ershkov
Institute for Time Nature Explorations,
M.V. Lomonosov's Moscow State University,
Leninskie gory, 1-12, Moscow 119991, Russia.

Keywords: Tsunami, earthquake, shallow water, deep ocean, wave height, protection seawall, the line of coast’s profile, shock wave, catastrophe theory.

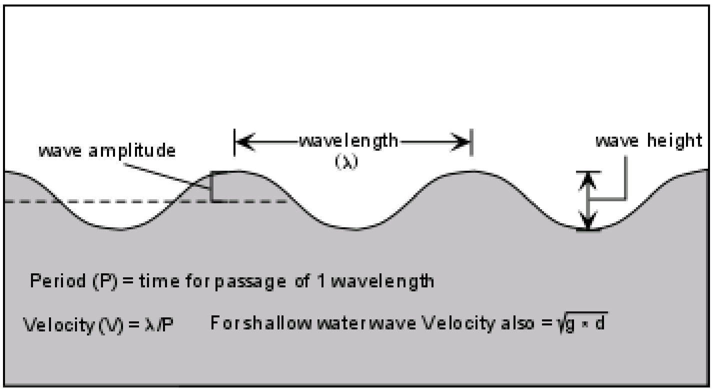
Here is presented an estimating range of heights of tsunami which is assumed to attack the coast after earthquake or something else. The height of tsunami is proved to be not less than 20 meters. For the reason above, **required height of seawall** for protection from Tsunami **should be not less than 25 meters**.

If tsunami overcome some suddenly rising the line of coast’s profile, such a giant wave is proved to decrease a velocity, as well as suddenly increase height. It so called gradient catastrophe in regard to the proper components of tsunami velocity (*shock wave*).

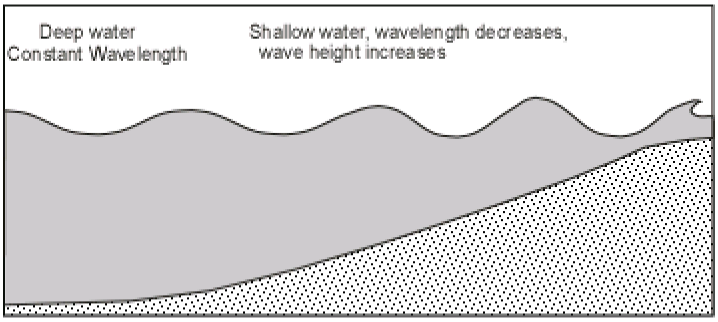
In accordance with [1-2], the velocity of a shallow-water wave is equal to the square root of the product of the acceleration of gravity, *g* and the depth of the water, *H*:

$$V = \sqrt{g \cdot H} \tag{1}$$

A tsunami in the deep ocean has a wavelength of about 200 kilometers [1]. Such a wave travels at well over 800 kilometers per hour , but owing to the enormous wavelength the wave oscillation at any given point takes 20 or 30 minutes to complete a cycle and has an amplitude of only about 1 meter (*see* [2]):



At the stage of free propagation of the wave in the open ocean at large depth, tsunami is known to be of ~ 1 meter height [3]. When the wave enters shallow water, it slows down and its amplitude (height) increases, *see* [2]:



During tsunami run-up onto the beach, it's height suddenly increases **not less than 20 meters**. Indeed, let's obtain it below:

- If we assume the mass flow rate of water *is the same per unit time*, it means that masses of water which pass through a proper surfaces (*per unit time*) are equal to each other

$$\rho \cdot V_1 \cdot \Delta L \cdot (H_1 + h_1) \;=\; \rho \cdot V_2 \cdot \Delta L \cdot (H_2 + h_2) \qquad (2)$$

- here ΔL – is a proper part of wavelength, V_1 - is velocity of Tsunami before striking on the beach, H_1 - is a proper depth of gulf in open ocean and h_1 - is a height of Tsunami; V_2 - is velocity of Tsunami after tsunami run-up onto the beach ($V_2 < V_1$), H_2 - is a depth of gulf near the beach ($H_2 < H_1$) and h_2 - is a height of Tsunami after run-up onto the beach ($h_2 > h_1$).

Substituting of the expressions for V_1, V_2 from **(1)** into above equation **(2)**, we obtain:

$$g \cdot H_1 \cdot (\Delta L \cdot (H_1 + h_1))^2 \;=\; g \cdot H_2 \cdot (\Delta L \cdot (H_2 + h_2))^2 \,,$$

$$\Rightarrow \quad h_2 \;=\; (H_1 + h_1) \cdot \sqrt{H_1 / H_2} - H_2 \qquad (3)$$

An expression above for the height of Tsunami is the simple estimation relying on simple representation of Continuity equation in fluids. Real process of tsunami run-up onto the beach could be represented only in terms of catastrophe theory [4]: when tsunami overcome some suddenly rising the line of coast's profile, giant wave is proved to decrease velocity [2-3], as well as suddenly increase height [3].

It so called gradient catastrophe [4] in regard to the proper components of tsunami velocity [5] (*shock wave*).

Let us model an expecting height of Tsunami:

1) If Δh_1 = 1 meter (*only*), we obtain:

H1	h1	Δ h1	H2	calculated h2 (*height of Tsunami on the beach*)	H2 + h2	Δ = (H2 + h2) - (H1 + h1)
100	1	1	99	2,5	101,5	0,5
95	2	1	94	3,5	97,5	0,5
90	3	1	89	4,5	93,5	0,5
85	4	1	84	5,5	89,5	0,5
80	5	1	79	6,5	85,5	0,5
75	6	1	74	7,5	81,5	0,5
70	7	1	69	8,6	77,6	0,6
65	8	1	64	9,6	73,6	0,6
60	9	1	59	**10,6**	69,6	0,6
55	10	1	54	**11,6**	65,6	0,6
50	11	1	49	**12,6**	61,6	0,6
45	12	1	44	**13,6**	57,6	0,6
40	13	1	39	**14,7**	53,7	0,7
35	14	1	34	**15,7**	49,7	0,7
30	15	1	29	**16,8**	45,8	0,8
25	16	1	24	17,8	41,8	0,8
20	17	1	19	19,0	38,0	1,0

2) If Δh_1 = 3 meters, we obtain:

H1	h1	Δ h1	H2	calculated h2 (*height of Tsunami on the beach*)
100	1	3	97	5,5
95	2	3	92	6,6
90	3	3	87	7,6
85	4	3	82	8,6
80	5	3	77	9,6
75	6	3	72	10,7
70	7	3	67	11,7
65	8	3	62	12,7
60	9	3	57	**13,8**
55	10	3	52	**14,8**
50	11	3	47	**15,9**
45	12	3	42	**17,0**
40	13	3	37	**18,1**
35	14	3	32	**19,2**
30	15	3	27	**20,4**
25	16	3	22	21,7
20	17	3	17	23,1

3) If Δh_1 = 5 meters, we obtain:

H1	h1	Δ h1	H2	calculated h2 (*height of Tsunami on the beach*)
100	1	5	95	8,6
95	2	5	90	9,7
90	3	5	85	10,7
85	4	5	80	11,7
80	5	5	75	12,8
75	6	5	70	13,8
70	7	5	65	14,9
65	8	5	60	16,0
60	9	5	55	**17,1**
55	10	5	50	**18,2**
50	11	5	45	**19,3**
45	12	5	40	**20,5**
40	13	5	35	**21,7**
35	14	5	30	**22,9**
30	15	5	25	**24,3**
25	16	5	20	25,8
20	17	5	15	27,7

Thus, we conclude that taking into consideration the above range of calculated heights of Tsunami, **the required height of seawall** for protection from Tsunami **should be not less than 25 meters** (*photo below* [1]):

References:

1. Wikipedia, S. *A New Kind of Science.* Champaign, IL: Wolfram Media, p. 918, 2002. See also: http://en.wikipedia.org/wiki/Tsunami.
2. Prof. Stephen A. Nelson (28-Jan-2009). "Tsunami". Tulane University. http://www.tulane.edu/~sanelson/geol204/tsunami.htm. Retrieved 2009-09-09.
3. Gusiakov V.K. Tsunami quantification. How we measure the overall size of tsunami (*review of tsunami intensity and magnitude scales*): http://www.ngdc.noaa.gov/hazard/data/presentations/jtc/gusiakov.pdf
4. Arnold V.I. Catastrophe Theory, 3rd ed. Berlin: Springer-Verlag, 1992.
5. Ershkov S.V., Schennikov V.V. Self-Similar Solutions to the Complete System of Navier-Stokes Equations for Axially Symmetric Swirling Viscous Compressible Gas Flow // *Comput. Math. and Math. Phys. J.* (2001) Vol.**41**, № 7. P.1117-1124.