Hydro-engineering and environmental problems in Poti Black Sea region and ways of their solution

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Work is dedicated to the development of hydro-engineering and environmental protection measures in the Black Sea regions, the main Georgian port of Poti at the mouth of the Rioni, which will minimize the region geomorphological changes caused by the influence of natural and anthropogenic factors, and will over a long period protect coastal areas of these regions from washouts and large scale silting processes.

The serious environmental problems started in Poti after transfer of the main flow of the river Rioni to the north. As a result, the flooding of the city stopped, but the reduction of water consumption in the city channel, caused a decrease of the sediments carried away by the river, what leads to coastal erosion. The coast changes are connected with the movement of the waves and currents in the coastal part of the sea.

The research objects are (Fig. 1):

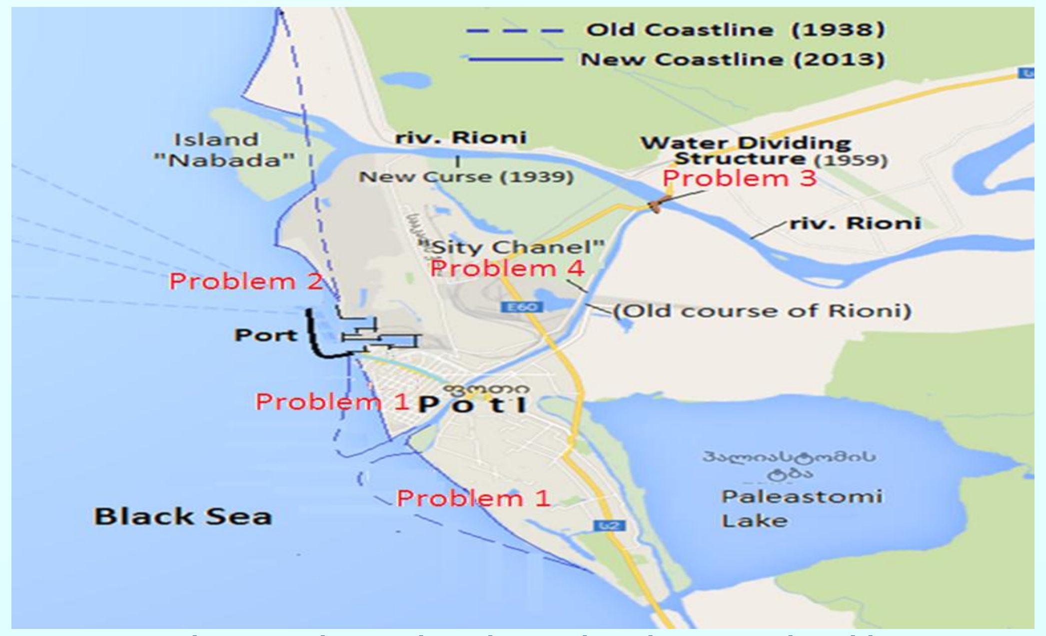

Fig. 1. Hydro-engineering and environmental problems map in Black Sea, Poti region.

1. Poti seashore, which has retreated for hundreds of meters, promoted with the existence of underwater canyon along the southern pier of the port;
2. Input Channel -The problem of protecting the port of Poti on the sediment deposits;
3. The Rioni river watershed dam, the tailrace of which in time was subjected to destruction and substantial washout. Currently the stability of the dam is endangered;
4. "City Canal" - the Rioni River old bed, which is greatly silted up and is virtually unable to perform its function – to feed Poti seashore with solid matter.

model of wave motion. The basic equation of wave motion are of the form:

$$\frac{\partial \vec{Q}}{\partial t}+\frac{c^2}{n}\vec{\nabla}(n\zeta)+f\vec{Q}=0,$$
$$\frac{\partial \zeta}{\partial t}+\vec{\nabla}\cdot\vec{Q}=0$$

Where - $\vec{Q}$ vector fluid flow, $\vec{Q}=\int_{-h}^{\zeta}\vec{u}dz$; $\zeta(t,x_1,x_2)$ - the free surface of the calm sea level elevation; n - The group velocity c_g related to the phase velocity c; f - coefficient bottom friction; h - water depth. There have been well-known relationships:

$$\sigma^2=gk\cdot th(kh),\ c=\frac{\sigma}{k}=\sqrt{\frac{g}{k}\cdot th(kh)},\ n=\frac{c_g}{c}=\frac{1}{2}\left(1+\frac{2kh}{sh(2kh)}\right),$$

Where – $\sigma=\frac{2\pi}{T}$ angular frequency; $k=\frac{2\pi}{L}$ wave number;

$T,\ L$ - respectively, period and the wavelength.

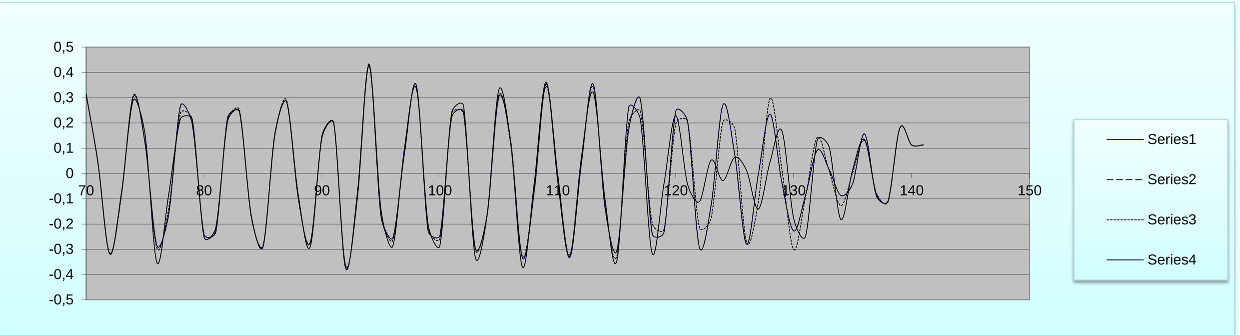

Fig.2. Changes in the free surface elevation of the sea near the coast ($i=70-141$).

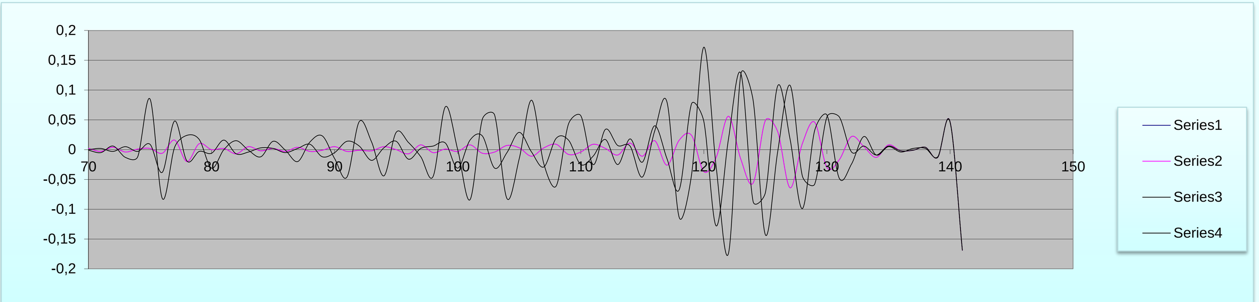

Fig. 3. Changes in the cross-flow near the shore.

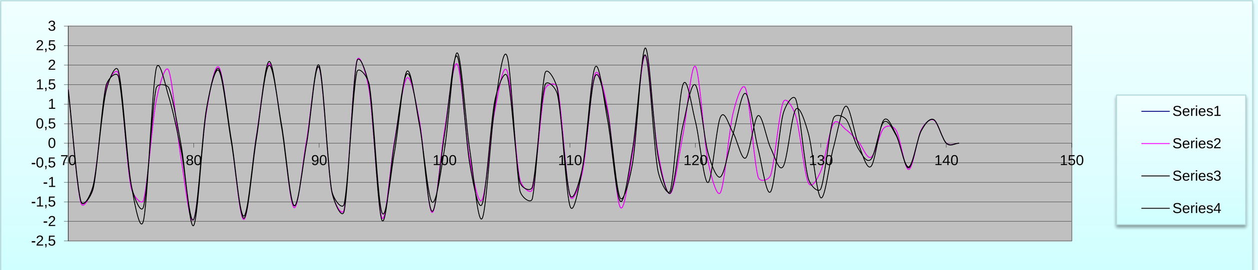

Fig. 4. Change the flow along the shore near the shore.

models coastal currents.

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}+F_x-M_x+R_x+g\frac{\partial \zeta}{\partial x}=0;$$
$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+F_y-M_y+R_y+g\frac{\partial \zeta}{\partial y}=0;$$
$$\frac{\partial \zeta}{\partial t}+\frac{\partial (h+\zeta)U}{\partial x}+\frac{\partial (h+\zeta)V}{\partial y}=0,$$

Where - R_x and R_y - components of the radiation stress; F_x and F_y - bottom friction components, M_x and M_y - mixes the components side (diffusion due to turbulence).

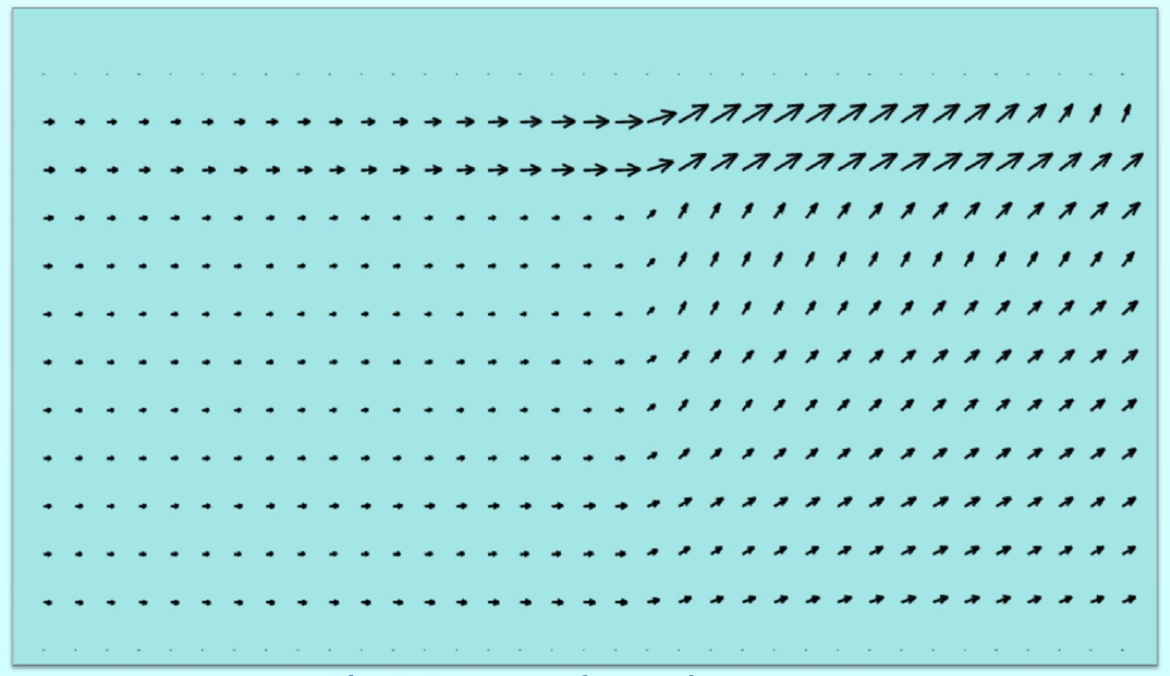

Fig. 5. Fragment of coastal current.

model of sediment transport and changes in bottom topography

$$\frac{\partial h}{\partial t}=\frac{\partial \tilde{q}_x}{\partial x}+\frac{\partial \tilde{q}_y}{\partial x},$$
$$\tilde{q}_x=q_x+\varepsilon_s|q_x|\frac{\partial h}{\partial x},\qquad \tilde{q}_y=q_y+\varepsilon_s|q_y|\frac{\partial h}{\partial y},$$

To determine the sediment transport rate we have:

$$(q_x,q_y)=(q_{cx},q_{cy})+(q_{wx},q_{wy}),$$

Where x and y - the horizontal position; q_x and q_y the velocity of sediment transport within the cell and on the direction x and y; (q_{cx},q_{cy})- sediment transport caused by the averaged currents; (q_{wx},q_{wy}) - sediment transport caused by the waves.

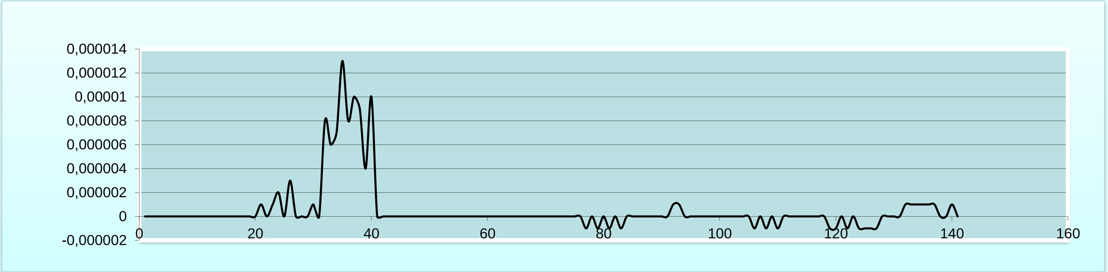

Fig. 6. The rates of sediment transport q_y at different (i,j). Speed q_y sediment transport for $i=1,\dots,141,\ j=5$

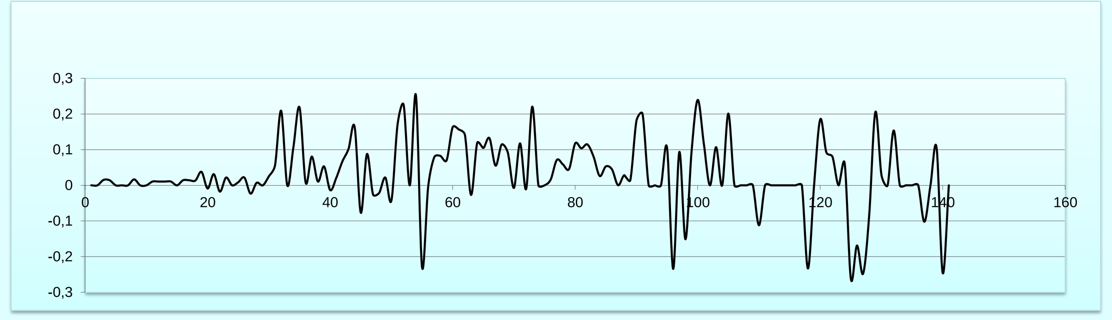

Fig. 7. Changing the topography of the bottom Δh hat various (i,j).

The numerical modeling was developed in three stages. In the first stage the topography of the coast and the initial geometry of the structures are considered as an input parameters. Then, coastal wave field is calculated for the conditions prescribed in the initial wave. In the second stage, the calculated wave field is used to estimate the spatial distribution of the radiation stresses near-bottom orbital velocity. In the third stage, the coastal wave fields and flow fields are used in the sub-models of sediment transport and changes in the topography of the coast.

In the numerical solution of basic equations of motion of the waves, coastal currents and changes in sea bottom topography we use: finite element, finite difference methods, and the method of upper relaxation, Crank-Nicolson scheme.

As an example, we are giving the results of research of the wave regime in the coastal area of the city of Poti (700X600m) adjacent to the port of Poti. The bottom profile, in this area is rather complicated. During the calculations of the average rise of sea level, 0.1m was taken as the initial value, which corresponds to the actual conditions.

The calculations have found that in the excitement, the sediment transport rates at a depth of 10-15m are almost zero. The maximum value of the velocity of sediment transport change within 0.006-0.0065m2/s.

In the case of the western waves, it is essential for long shore sediment transport directions, which varies in the range 0.0015-0.0022m2/s. The rate of sediment transport perpendicular to the bank in this case is irrelevant, and their maximum values in the range 0.00001-0.000017m2/s. Changes in the water depth varies from -0.25 to 0.29m. The rate of coastal erosion south of the port of 8-10m/year.

To protect the coastal zone is essential consumption beach forming sediments that are distributed as follows:
- 200000 m3 /year in the southern channel;
-650000 m3 /year In the northern channel.
Deficit material of making seashore in the southern channel is 200000 m3 /year. Mathematical modeling gave approximately the same results.

A conceptual design of bank protection measures, which uses a new idea of bottom diversion of river sediments from the northern channel of the river Rioni in the southern channel. The basic design and operating parameters of hydraulic equipment for lifting of bottom sediment. It is proposed a feasibility study of the proposed bank protection measures in the region of Poti. According to economic indicators and the reliability of the proposed project exceed the previously proposed projects to protect the shore from erosion near the town of Poti.

The results obtained using these models will be put as a base of development of such engineering measures and design proposals which:
a) will provide sustained increase of Poti coastal line on the basis of working out of exploitation regimes of the Rioni watershed hydro complex and as a result of performing additional engineering measures in "City Canal";
b) will thoroughly protect the Rioni watershed hydro complex dam tail-water from destruction and washouts;

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