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Gumati and Vartsikhe Power Plants' Impact on the River Rioni New Delta Development

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ABSTRACT

Based on analysis of the volume change of the sediment, brought to the sea by the River Rioni, was estimated the state of the seacoast, neighboring estuary of the Black Sea. The relief of the Black Sea coast and its dynamics greatly depend on the sediment, brought by rivers. In Georgia reduction of the amount of the sediment, brought by rivers mainly is caused by an anthropogenic factor. The submarine canyons' influence on the morphology and dynamics of the coast are also important. It was always difficult to determine the proportion of man-made and natural factors on the accumulative coasts of the River Rioni Black Sea estuary. The possibility to evaluate such processes appeared based on the analysis of the sequence of the events which took place in the River Rioni delta after 1939. Here is offered the forecast of the development of the section next to the River Rioni estuary of the Black Sea.

***Key words*:** Submarine canyon, river sediment, litho-dynamic system

Introduction

The largest part of the Georgia's Black Sea coastal zone genetically belongs to accumulation type and its present-day sustainability greatly depends on the river sediment [1,2,3]. In natural conditions, the volume of river sediment annually brought to the sea is sufficient, and in some cases more than sufficient, for providing of the positive balance of the coastal zone. In cases, when the volume of river sediment for various reasons is declining, coastal and underwater slope begins to react accordingly. This process is mainly expressed by the coast washout and change of the underwater profile. At present, reduction of the river sediment mostly is caused by the man-made impact because of extraction of the sediment from the river beds or their containment by the dams. In this case, it is difficult to determine the degree of the negative impact and quantitative indicators, as the sediments from the coastal zone are lost on steep slopes of submarine canyons and accumulative capes. The possibility to evaluate such processes appeared based on the analysis of the sequence of the events which took place in the River Rioni delta after 1939. In the new mouth developed the powerful accumulation processes, in consequence of which was formed a new delta on the area of 1300 hectares. The sediments, brought by the rivers to the accumulative coasts play major litho-dynamic role in the formation of beaches and submarine slope. The Alluvium, come from the rivers to the marine estuaries intermixes with the sediment here and forms a talus fan, which is mostly made up of sediments of relatively large fractions. Small fractions spread farther from the shore and are deposited on the underwater slope.The relief of the underwater slope itself conditions the outline of the coast and morphometry, petrographical and granulometric composition of the beaches. The submarine canyon heads, located near the coastline significantly influence the coast construction and lithodynamics [4,5,6,7]. In sum, the sediment, come from the rivers, in consequence of sea storms and flows influence participates in complex litho-dynamic processes, resulting in creation of large accumulation forms. They, in most cases,

after passage of several stages of development tend to a stable condition [8]. For example, in the coastal zone of Georgia Kakhaberi and Kolkheti coastal lowlands, Sukhumi, Pitsunda, Kodori and Batumi accumulative capes belong to the similar forms [9,10]. The mentioned accumulative forms and the contemporary appearance of the coastal zone of Georgia was formed about 5-6 thousand years ago, when after the rapid rise the Black Sea level it has reached the current situation [11]. Along the persistent coast was formed the local ecosystem with its characteristic ecotones in the river estuaries and deltas [12].

Depending on the amount of sediment brought to the sea by rivers, they can be divided into 3 groups. In the first group are the great rivers, bringing much more sediments to the sea, than the sea waves and currents along the shore can move [13]. In this case, the river estuaries should be subjected to continuous accumulation. In fact, this process is not observed, because in front of all big rivers of the sea side of Georgia are located submarine canyon's heads. The most part of river sediment is lost in such canyons; however, the necessary amount for the stability of the coast escapes the canyon head and is distributed along the sea coast. In some respects the mouths of rivers near the submarine canyons, accomplish a function of natural sediment distributor [14], by means of which the coastal zone maintains its stable condition.

The second and third group rivers bring to the sea less amount of sediments, the volume of which is always less than the transporting ability of wave energy. The total amount of the mentioned river sediments is completely spent for feeding the coast and to some extent is involved in the formation of the litho-dynamic systems. Their mouths do not take the form of delta and more or less keep the coastline azimuth, existing within the litho-dynamic system scope [9,10].

The region of studies, material and methods

River Rioni belongs to the above examined first group and its estuary is located in the center of the eastern part of the Black Sea. Here are the beaches of fine sand, which is characteristic for the Rioni litho-dynamic system [15,16]. The average inclination of the profile of the underwater slope, having dynamic equilibrium, varies within the frames of $tg\alpha = 0{,}007\text{-}0{,}009$ ($0^0 27'' - 0^0 30''$). In the submarine canyon source area of Poti (Rioni) the profile is unstable and its inclination is $tg\alpha = 0{,}03 - 0{,}038$ ($1^0 43'' - 2^0 12''$). Immediately in the underwater canyon head, which begins from a 7-meter depth, the inclination varies within the scope of $2^0\text{-}4^0$. Towards the greater depth the canyon thalweg gains great inclination, which in some places reaches $20^0\text{-}25^0$. Canyon side skirts are characterized by quite a large inclination, and in some cases equal 45^0 [17,18].

The underwater slope surface Poti (Rioni) litho-dynamic system till the depths of 8-10 meters is composed of fine silt sand. The main source of feeding of coast beaches and underwater slope sediments is the River Rioni. In the natural conditions, the river solid sediment volume was approximately 8-10 million m^3 per year, which was 7-8 times higher than the waves' and currents' transporting energetic capacity. Thus, the main part of the amount of sediment was flowing into the submarine canyon, otherwise in the old mouth of the River Rioni would continue constant accumulation and, accordingly, growth of the coastal land. Based on the analysis of historical cartographic materials it was revealed that within the frames of the old delta were passing pretty intense periodic changes, though it was due to the natural migration of river branches and distribution of the liquid and solid flows among the branches. In any case, regardless of the mentioned changes, the largest volume of the River Rioni sediment, in the second half of the Holocene, was moving to the great depths of the submarine canyon, from where it could not return to the upper part of the shelf again [19,4].

In 1873 began construction of the port of Poti, arrangement of the south end of which was completed in 1888. The port got its final appearance in 1905. The constructed port disturbed the conditions of alongshore distribution of the sediments, coming from Rioni – it did not let them pass any more to the north. In fact, the litho-dynamic system was divided into two parts – the south and north coasts from the port. Because of this in the old mouth of the Rioni began intensive accumulation of sediments, both on land and in the upper part of the underwater canyon. The sea waves could no longer distribute equally such a large volume of sediment, and the large volume of accumulated on the steep slopes mass, due to gravitational

forces from time to time was moving instantly to the great depths. As a result, erosion processes under the water were activated, causing movent of the canyon head in the direction of the coast and the constructed mole. They began to sink old barges and the vessels in the canyon head to stop the canyon's movement forward, but the accomplished measure could not stop the ongoing movement of canyon towards the coast [20].

The course of litho-dynamic processes was radically changed since 1939, when the main bed of the River Rioni was displaced and its new estuary turned out to be north of the port. Thus, the river estuary was moved away from the submarine canyon head. These changes caused a unique opportunity for research. Specifically, it was the study of the River Rioni solid sediment sedimentation process for average years long profile of the surrounding underwater slope. In the newly created estuary, loss of river sediment fell to a minimum, because the great depths of the underwater slope were located quite far away from the shoreline. Therefore, most of the river sediment after entering the sea was settling down on the underwater slope, in front of the new estuary. The small fractions of suspended sediment in the water extend far from the shore and its quantity is hard to measure, though, as it is known, it is not considered as a coast forming sediment [21,22].

The shape of the Black Sea coast zone, where the River Rioni branch has created a new main estuary, was making a linear and slightly concave arc having 170 ° azimuth, along the coast were sandy beaches with full profile, the width of which was varying between 60-80 meters. The coast was stable and was fed mainly with the rivers Rioni and Khobi sediments. After the construction of the port feeding of the coast from the River Rioni stopped, but the River Khobi sediment was enough for the sustainable development of the coast. The sedimentsalongshore streamwasdirectedfrom the River Khobi estuary towardssouthandits flow was aboutabout 50-70 th. m^3 peryear. Until 1939 sediment was accumulating near the Poti port and this was not favorable for the marine navigation. Because of silting of the entrance channel of the port the port administration was conducting periodic deepening the bottom, but the volume of the work completed at that time was not large and it did not make severely negative influence. Today, the shore, located between the port of Poti and River Khobi in litho-dynamic terms, can be considered as an independent segment, the sediment balance of which is positive - that is, loss of sediment or its migration to other areas is not observed.

For study of the River Rioni new delta were used the old cartographic materials, which were compared to a new survey. Based on the materials were calculated areas of increase of land and volumes of accumulation up to 20 meters depth (Table 1).

Results and discussion

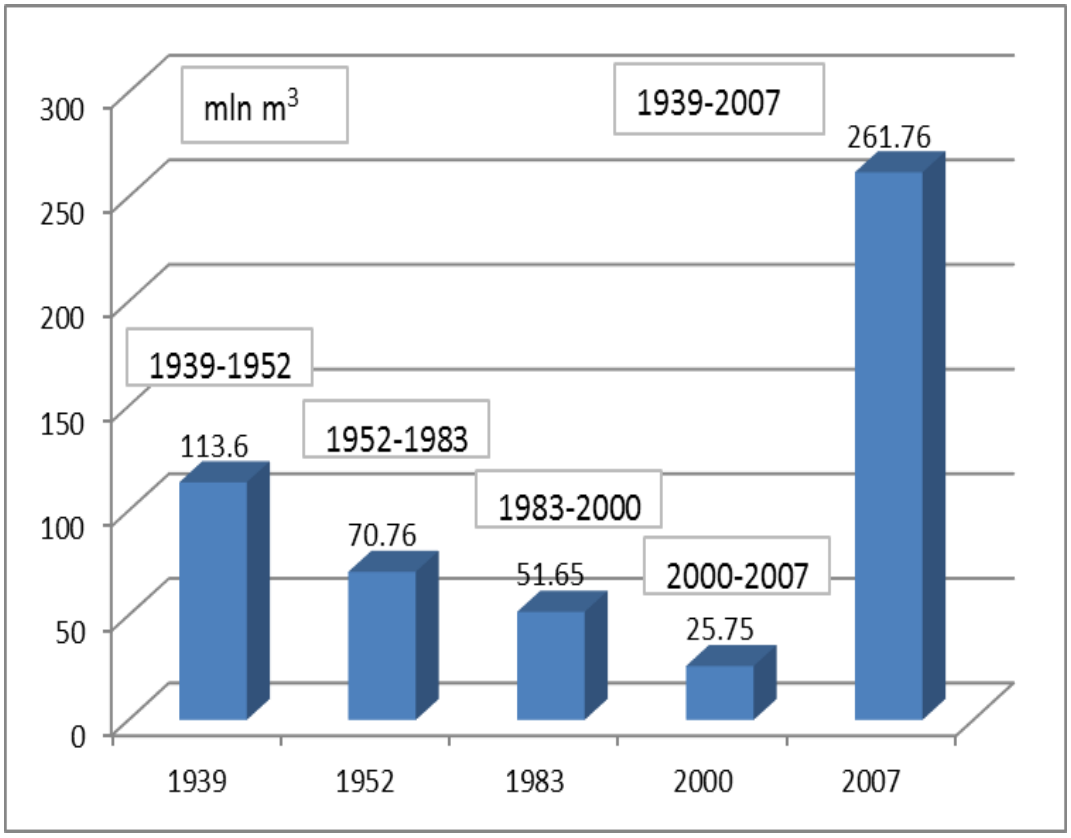
After displacement of the main flow of the river to the north, the coastal zone has undergone significant changes. By 2010, the coast on the south of the port, suffered a washout, in consequence of which the sea has swallowed the area of 300 hectares of land. In addition, in the north of the port, a strong accumulation caused increase of land by 1 300 ha. Overall, in the Rioni litho-dynamic system terrestrial increment was 4.3 times larger than the area of washout. The absolute value of the increase made 950 ha. The area of land surplus would be higher, if not annual extractions of sediments from the Poti port entrance channel. In consequence of deepening works the total volume of the sediment removal, ranging from 1939 to the present, made about 35-40 million m^3. Construction of power plants of Gumati - 1956 and Vartsikhe – 1976 has made the greatest impact on the river sediment reduction. The river sediment volume has been reduced also about by 300-400 thousand m^3 after 1959, when were built the watershed dam and flood gate-regulator, by means of which a part of the liquid flow moves in the direction of the city. Nevertheless, powerful river accumulative process in the estuary and its adjacent coastal area has not stopped, but its speed greatly reduced. This fact shows how great was the impact of the submarine canyon on the coastal zone development (see Figure 1). Overall, in the north of the Poti port was formed a new delta of the River Rioni. By 2005, in both estuaries of the delta emerged the islands, and this indicates that the delta development passes to a multi-branch stage. Table 1 –in 1939-2007 years in the coastal zone between the

River Khobi and Poti port were accumulated 261.76 million m³ sediments. Taking into consideration the volumes of deepening of the entrance channel, it appears that there would be accumulated approximately 300 million m³ (Nomogram 1).

Table 1

The land growth and sediment accumulation in the River Rioni new delta (from the Poti port – to the River Khobi estuary) in 1939-2007 years.

Observations' years	Accumulation to the depth, m	Accumulation, million m^3	Average per year million m^3	Land increase, ha	Average per year, ha
1939 - 1952	10	64.07	4.93	537	41,3
	20	113.6	8.74		
1952 -1983	10	34.14	0.98	327	10,5
	20	70.76	2.02		
1983 - 2000	10	28.29	2.02	234	13,1
	20	51.65	3.03		
2000-2007	10	11,37	1.62	106	15.1
	20	25.75	3.68		
1939- 2007	10	137.87	2.03	1204	17.71
	20	261.76	3.84		



Nomogram 1. The sediment volumes, accumulated in the coastal zone at different times

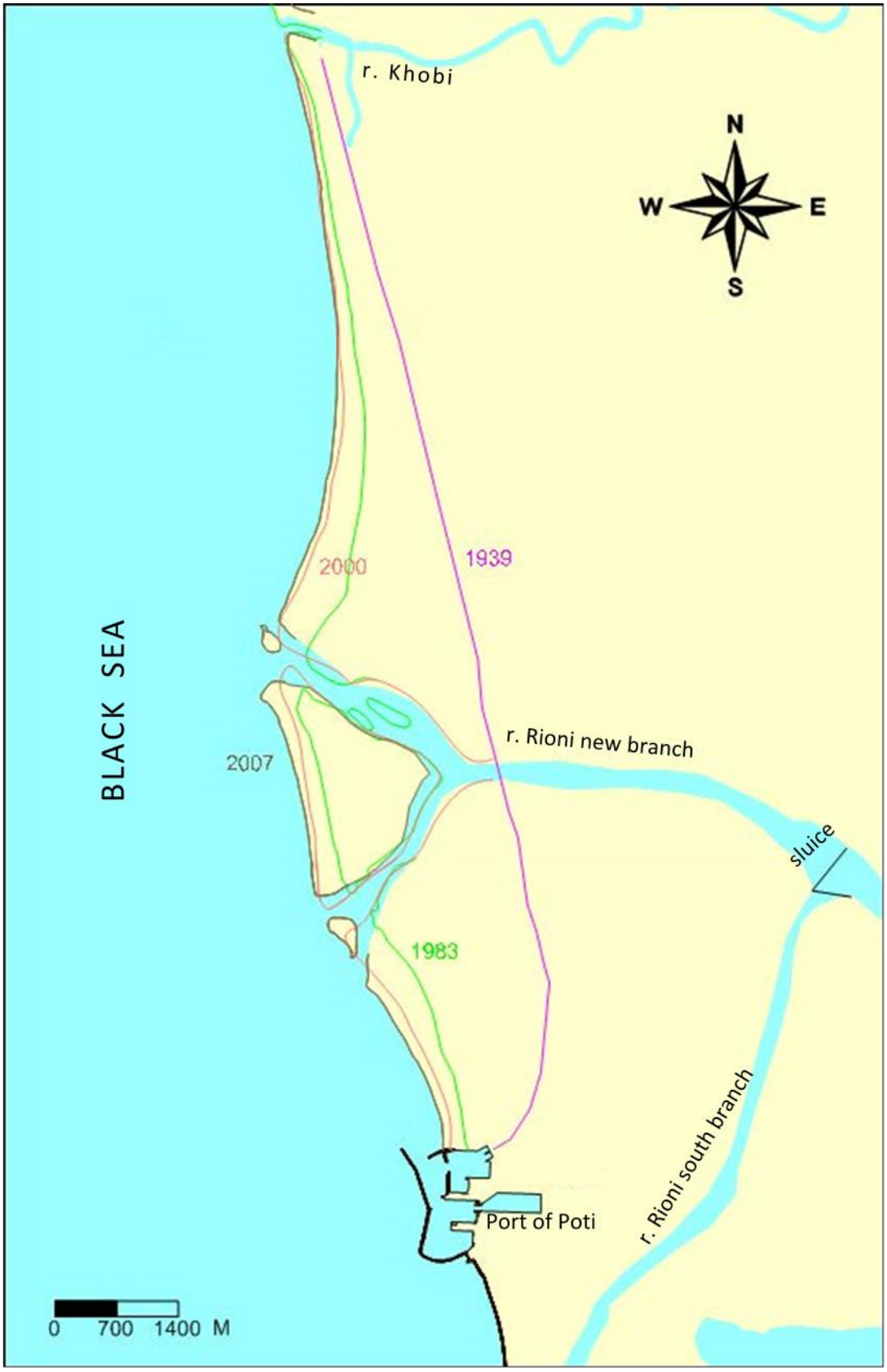


Fig. 1. Coastal zone development scheme during 1939 - 2007 years, between the port of Poti and the River Khobi estuary.

River sediment was significantly reduced in 1953, when was built the Gumati power plant dam. In 1959 was completed construction of the Poti dam and they started passing of a certain amount of liquid flow of the River Rioni in the direction of the city. In consequence the annual volume of the river sediment, directed to Nabada (the new estuary) reduced by about 300-400 thousand m^3. At the end of the sixties of the last century, Vartsikhe power plant came on-stream, significantly reducing the River Rioni sediment volume. Based on the analysis of existing materials the annual sediment accumulation in the 1939-1952 period amounted to 8.74 million m^3. After 1952, the accumulation of sediments in the delta has dropped 4.33 times and amounted to 2.02 million m^3 / year (Fig. 2).

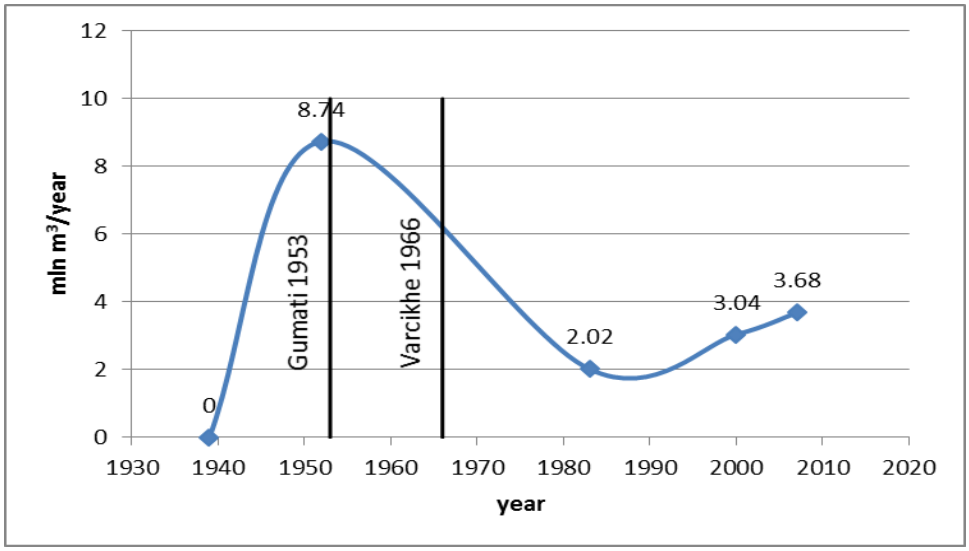


Fig. 2. The annual sediment accumulation volumes Between the mouths of Poti port and the River Khobi estuary.

Starting from the mid eighties the volume of sediment accumulation has risen and in 2007 increased by 1.8 times. This happened in consequence of filling of power plants' hydro reservoirs with sediment, which gradually led to passing of increased amount of sediment by the dams. Appropriately increased sediment accumulation rate, as it is shown on the cumulative curve (Fig. 3).

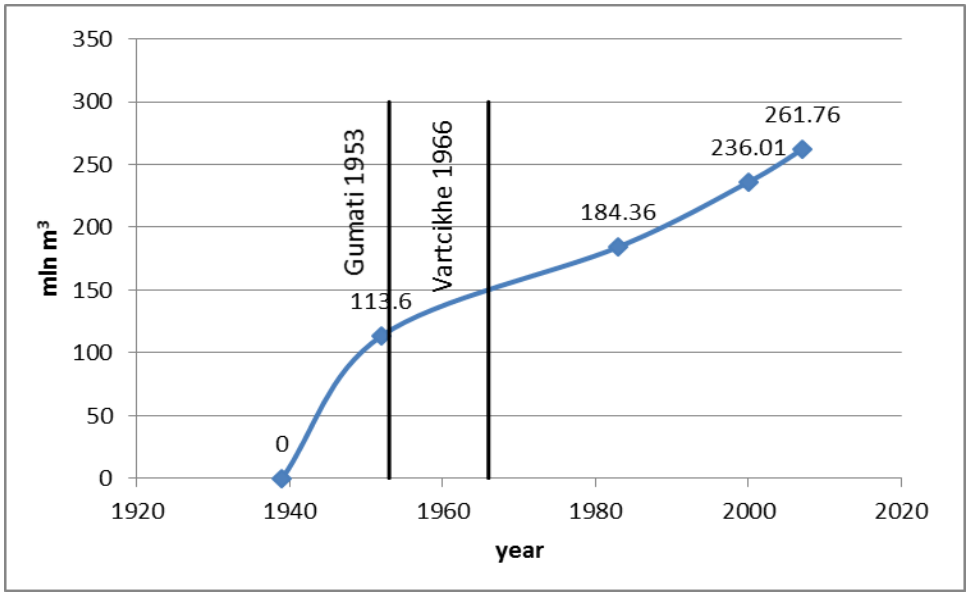


Fig. 3. Cumulative curve of the sediment accumulation.

Finally was formed an asymmetrical shape delta, the northern flank of which is much longer than the southern one. Here it should be noted that the new delta would have symmetrical form if not the Poti port hydraulic structures and permanent removal of sediment from the entrance channel. The azimuth of the delta north shoreline is 200°, which corresponds to the annual migration of 560 thousand m^3 of sediment in the north direction. The azimuth of the south direction shoreline is 168 ° corresponding to the annual migration of 370 thousand m^3 of sediment in the south direction. Sediment migration volumes are computed according to V. Sakvarelidze method [23].The mentioned method was giving good results for sandy beaches. Hence it can be said that the northern branch of the new delta brings to its sea mouth 60%of the total sediments and the southern branch - 40%. The azimuth of the delta central island's shoreline is 168 °. It is interesting that, wave field resultant vector is exactly perpendicular to the coastline of the island; it is deviated from the direction of the west towards south by 11 °. This means that here, in the coastal line, in the island section prevail equal values of the sediment bilateral migration, or sediment integral move in any direction is not observed. At present, the coastline in the scope of the island is advancing by 10-12 m / year speed. The rate of the delta south and north branches' increase in the first 300-meter sections respectively are 18 and 20 meters per year. The distance between the sea estuaries of the branches over time gradually increases. In 2000, for example, the distance between the 2 branches of the delta was 3080 meters and by 2007 it increased to 3 390 meters. The increase of the distance between the estuaries of the branches point to the activation of the general accumulation in the mentioned period, caused by filling of the power plants' reservoirs with sediment. In fact, the reservoirs were filled with sediment over the second half of the eighties of the last century and after that in the coastal zone is observed gradual growth of the annual accumulation volume and of surplus land (Fig. 2 and Fig. 4).

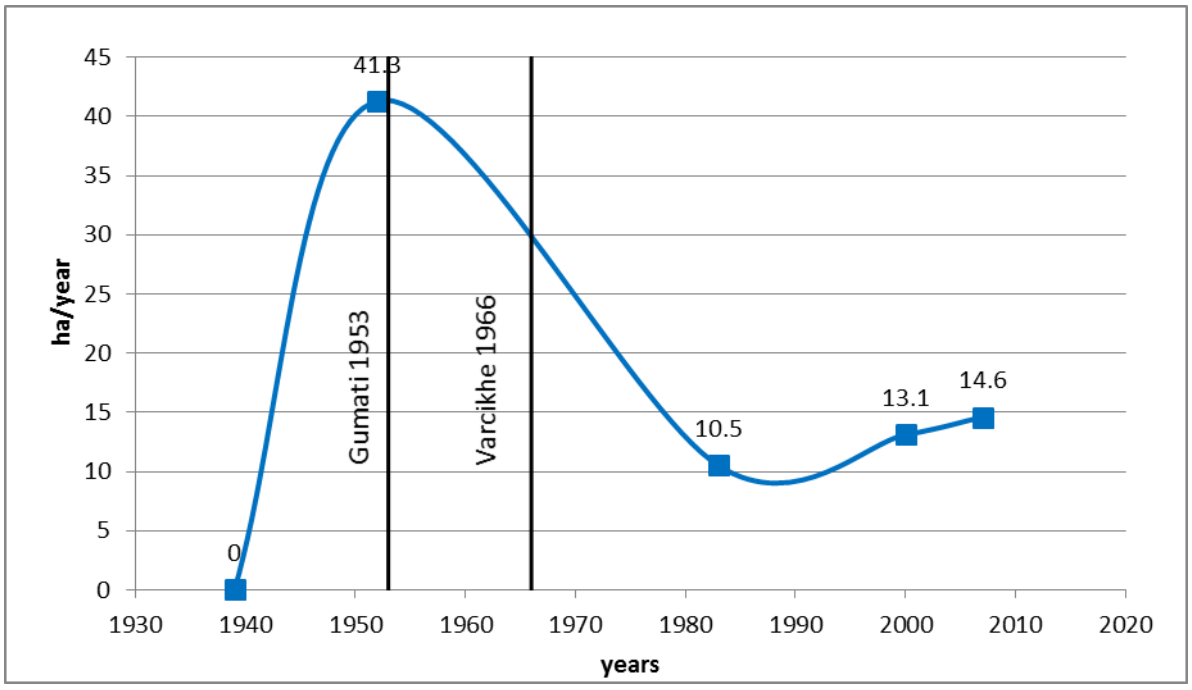


Fig. 4. The dynamics of the surplus land within the new delta scope.

As the Fig. 4 shows, by 1985 land increase rate was less than 10 ha / year. In the following years the rate has gradually increased and amounted to 14.6 ha / yearby 2007. It is expected that the rate of land surplus will further increase at the expense of the sediment increasing, and by 2020 will reach to 20 ha / year. Calculations show that if the power plants are not built, the overall gain of the land would reach the current figure i.e. 1204 ha at the beginning of the 70-ies of the last century (Fig. 5).

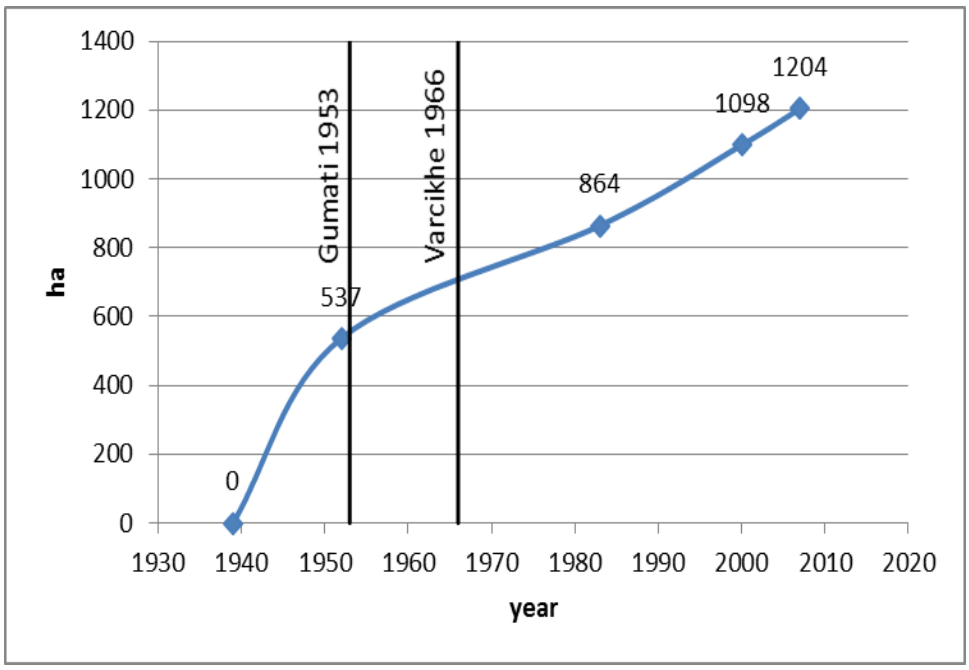


Fig. 5. The cumulative curve of the land area increase.

Unfortunately, no such observations were carried out on the River Rioni city channel sea estuary. Here, the water passing in the river upstream began in 1959, at the 7th kilometer from the estuary after the watershed dam was built, i.e. in the period, when the solid sediment entering was significantly diminished because of Gumati power plant. As is well known in this period the Poti coast experienced intensive wash-out. At present, during the visual inspection of the Poti coast can be observed the coastline stabilization, which is associated with a general increase of the River Rioni sediment. If the overall trend of increasing of the river sediment volume continues, bringing the sediments through the city channel will increase as well. In this case, it is possible to sustain the stability of the coastline, surrounding Poti.

Conclusion

In the conditions of increased amount of the sediment will be activated the accumulation processes within the new delta. The coastline progress rates will rise and accordingly nearby underwater slope sedimentation process will become more intense. In this case, Poti port will have certain problems, in the entrance channel of it will be activated silting intensity. If on the River Rioni new power plants are under construction, solid sediment amount will be reduced again. This will result in a significant decrease of the growth rate of the new delta and activation of washouts in the Poti coastal line.

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გუმათის დავარციხის ჰესების გავლენა მდ. რიონის ახალი დელტის განვითარებაზე

გ. ლომინაძე, ი. პაპაშვილი, გ. ყავლაშვილი

რეზიუმე

მდინარე რიონის მიერ ზღვაში შემოტანილი ნატანის მოცულობის ცვლილების ანალიზის საფუძველზე მოხდა შავი ზღვის შესართავისპირა სანაპიროს მდგომარეობის შეფასება. შავი ზღვის სანაპირო ზონის რელიეფი და მისი დინამიკა დიდად არის დამოკიდებული

მდინარეების მიერ შემოტანილ ნატანზე. საქართველოში მდინარეების მიერ ზღვაში შემოტანილი ნატანის რაოდენობის შემცირება ძირითადად ტექნოგენური ფაქტორითაა გამოწვეული. ასევე მნიშვნელოვანია წყალქვეშა კანიონების ზეგავლენა ნაპირის მორფოლოგიასა და დინამიკაზე. მდ.რიონის ზღვის შესართავის აკუმულაციურ ნაპირებზე ტექნოგენური და ბუნებრივი ფაქტორების ზეგავლენის პროპორციის განსაზღვრა ყოველთვის რთული იყო.პროცესები გაანალიზდა რიონის დელტაში1939 წლის შემდგომ განვითარებული მოვლენების შესწავლის საუფძველზე.შემოთავაზებულია შავი ზღვის სანაპიროს მდ.რიონის შესართავისპირა მონაკვეთის განვითარების პროგნოზი.

Влияние Гумати и Варцихе ГЭС на развитие новой морской дельты реки Риони

Г.Дж. Ломинадзе, И.Г. Папашвили, Г.И. Кавлашвили

Резюме

На основе анализа изменения объема наносов, транспортируемых р. Риони к морю, произведена оценка состояния и предложен прогноз развития приустьевого участка реки. Уменьшение объема материала, приносимого реками на побережье Грузии, в основном вызвано техногенными причинами. В морфодинамике береговой зоны Черного моря Грузии существенным также является фактор подводных каньонов. Оределение соотношения влияния техногенных и природных факторов на исследуемые аккумулятивные берега всегда было сложной задачей. Реальная оценка процессов стала возможной на основе анализа явлений, имевших местов дельте р. Риони после 1939 г., в связи с перераспределением ее стока. Предложен прогноз равития участка Черноморского побережья в дельте р. Риони.