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IMPACT OF ŠVENTOJI PORT JETTIES ON COASTAL DYNAMICS OF THE BALTIC SEA

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Abstract. As the safe depth for navigation is no longer ensured due to intense accumulation of sediments in the avanport of the old port, which was constructed in 1923–1940, reconstruction of Šventoji port jetties was planned, which should commence in 2013. The assessment of impact of Šventoji port jetties was done on the nearby coasts, based on analysis of the 20th and 21st century cartographic material as well as monitoring data on coastal dynamics. The old port construction caused the formation of the accumulative cape; the area of which has grown to 44.90 ha. The coastline erosion processes have become especially intense northwards from the formed cape to the Latvian border. Approx. 38.41 ha area of land has been washed-out in the section. During the last 17 years, the southern jetty has become more and more pervious to sediments. Sediment volume stabilization occurred on the northern side of the jetty, and accumulation tendency was in the southern part of the port.

Results of sediment transport modelling with MIKE 21 confirm that the reconstruction of Šventoji port according to alternative "1" (length of jetties – 400 m) answers the minimal requirements of port and makes the least impact for the hydrodynamic and lithodynamic processes in the Baltic Sea nearshore. The reconstruction of port according to alternative "2" (length of jetties – 800 m) will cause the intensive changes of the Baltic Sea coastline dynamics in adjacent regions.

Keywords: environment monitoring; environmental impact assessment; Šventoji port; coastal sediments; coast line dynamics.

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Introduction

Multi-purpose hydrotechnical constructions are inevitable attendants of human economic activities. Depending on a size and a design, these constructions change the patterns of hydro-morphodynamic processes in the coastal zone.

Relatively homogenous littoral linear landscapes comprising of sand or shingle beaches with foredune or cliff prevail in south-eastern coasts of the Baltic Sea. Due to specific spatial configuration (very big length compared to width), most littoral linear landscapes are especially sensitive to external factors (Nicholls, Mimura 1998; Doody 2001; Vermaat *et al.* 2005; Wolters *et al.* 2005; Jurkus, Povilanskas 2009).

Even though engineering constructions are projected after assessments of possible environmental impacts, the Lithuanian and global practice alike show that these preliminary assessments are rarely accurate (Komar 1983; Carter 1989; Van de Graaf *et al.* 1991; Haan 1992; Žilinskas 1998; Žaromskis 2008; Žilinskas *et al.* 2008, 2010; Jarmalavičius *et al.* 2012; Lashchenkov 1987).

The jetties of Klaipėda and Šventoji ports, and Palanga jetty with the protective groyne have a significant impact on the condition of the Lithuanian coast (Žilinskas 1998; Žilinskas *et al.* 2008, 2010; Žaromskis 2008; Jarmalavičius *et al.* 2011). The assessment of the impact that Šventoji port has on the condition of adjacent coasts is becoming especially relevant, due to the reason that the reconstruction of this port is planned to be started in 2013.

The aim of this article is to assess the impact of Šventoji port on the nearby coasts (starting from the beginning of port construction to the present day), based on analysis of the 20th and 21st century cartographic material as well as monitoring data on coastal dynamics, and also, to assess (using the results of computer modelling) the possible effects the port reconstruction might have on the adjacent coasts in the future.

1. Investigated area and methods

Šventoji port (Fig. 1a), previously called Heligaw, Heiligen-Aa, Heilygaw and the like, was functioning in the 16th–17th century, but was depredated by Swedes in 1701 and its fairway was lumbered up with rocks (Šimoliūnas 1933; Žulkus, Springmann 2001). In 1918, when Lithuania regained its independence, it was decided to revive Šventoji port.

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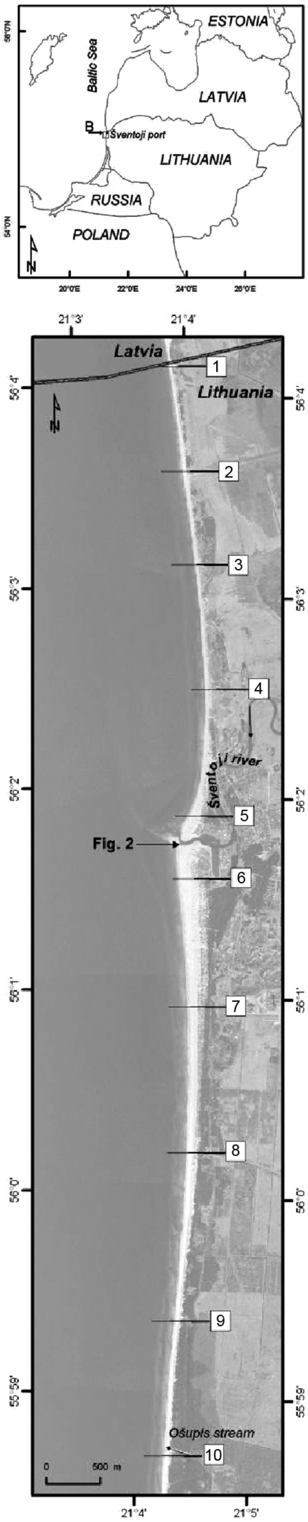

Fig. 1. Location map: study area and measuring profiles (1–10)

At the time, three stages of Šventoji port construction and development were planned (Fig. 2a).

The first stage was intended to construct a small littoral fishing harbour, jetties of which were up to 3–3.5 m of sea depth. The second stage was intended to extend the southern jetty to 5–5.5 m depth and construct a new northern jetty for open-sea fishing boats. During the third stage of construction, the jetties had to achieve 7–8 m depth, in order to be able to accept trading ships (Šimoliūnas 1933). The 380 m long southern jetty was constructed in 1925, and the 228 m long northern jetty was constructed in 1926. There was a 60 m wide harbour gate left between the jetties. However, after the first-stage construction works in avanport were finished, the silt began to accumulate in the port. Therefore, to protect the avanport from choking with silt, construction of long jetties was started in Šventoji in 1939, this way overrunning the works planned to be done in the second stage (Fig. 2a).

a)

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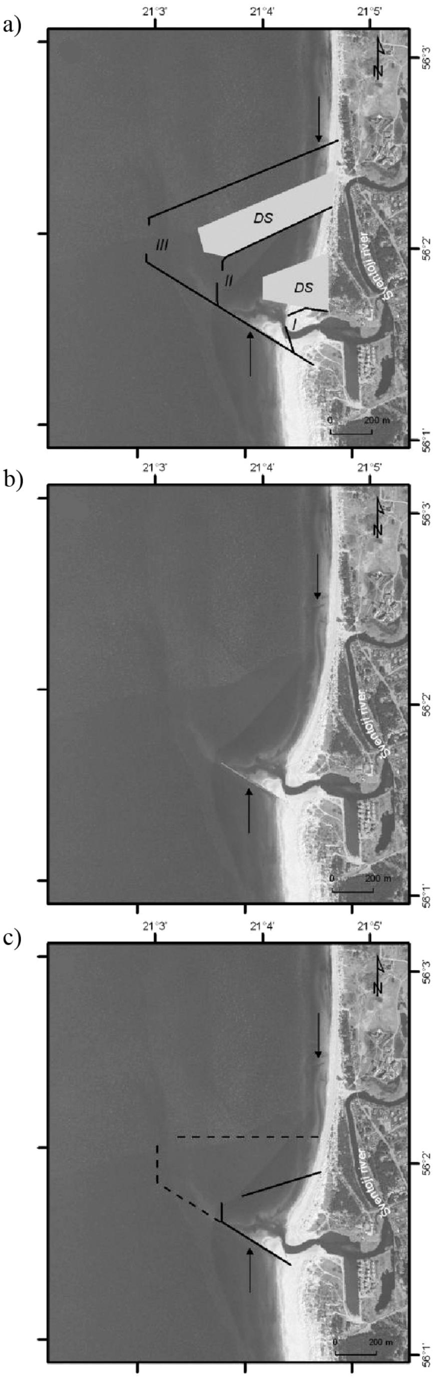

Fig. 2. Šventoji port development: a) construction and development project in 1925–1940 (I–III port construction stages), DS – plans to form overland of the spilt soil; b) current condition of the port, arrows show place of jetties: c) alternative "1" (length of jetties – 400 m) and alternative "2" (length of jetties – 800 m) of Šventoji port reconstruction in future

The new southern jetty with the length of 780 m was constructed in 1939, and the construction of the northern jetty began in 1940 (Fig. 2a); however, as soon as first 120 m were constructed, the Second World War terminated all works. After the War, when Lithuania regained Klaipėda port, the construction of Šventoji port was not continued. For a more detailed analysis of Šventoji port construction history, see the works written by Šimoliūnas (1933), who directly participated in the port construction, as well as the works of Merkys (1934) and Žaromskis (2008).

The assessment area, with Šventoji port in the centre, covered approximately 10.1 km long coastal line from the Ošupis stream in the South to the Latvian border in the North (Fig. 1b). Though the morphology of the entire coastal line analyzed is similar (beach and foredune of littoral dunes), the morphometric coastal parameters differ. The southern jetty of Šventoji port and the mouth of the River Šventoji divide the analyzed area into two parts: southern (Šventoji port – Ošupis stream) and northern (Šventoji port – Latvian border) (Fig. 1b). On the basis of monitoring data, a short assessment of the current morphodynamic condition of the coastal area analyzed is provided below.

The *Šventoji port – Ošupis stream coastal sector* covers approximately 5.6 km (Fig. 1b). Its beaches are comprised of the fine-grained and medium-grained sand. The northern part of the line (approximately 1.3 km long section) has a wide beach (the mean width is 70 m).

A wide (80–110 m) and high (relative height is 6–8 m) foredune adjoins it. Approximately 1.3 km southward from Šventoji port, the beach begins to narrow significantly: from 60 m in the beginning of the section to 25 m at the Ošupis stream. The foredune also narrows down from 60 m in the beginning of the section to 15 m at the Ošupis rivulet, and lowers from 6 m to 3.5 m. A typical attribute of the foredune in the said section is a new generation embryo dune adjoining it on the western base.

The length of *Šventoji port – Latvian border coastal sector* is approximately 4.5 km (Fig. 1b). The surface of the southernmost 900 m section of the beach line (narrowing in the direction of North from 45 m to 27 m) is covered with fine-grained and medium-grained sand or, in some places, shingles. The mean foredune width here is 66 m. The height of its western slope is 1.5–2.0 m; it is slightly eroded by waves and much depredated. Northwards from the section (an area of approximately 1400 m in length) the beach narrows to 15–20 m. Medium-grained sand with admixture of coarse-grained sand and shingle prevails there. Foredune width is 25–80 m and relative height is 1.5–3.0 m.

Būtingė geomorphologic (dune) park begins at the northern side of the said section. The coastline length of the park is 1935 m, and the northern border coincides with Lithuanian – Latvian borderline. Narrow (25–35 m) and low (1.0–2.5 m) beaches of the park covered mostly with shingle are not capable to protect it from wave attacks even during the medium strength storms. Therefore, the western slope of dunes here gets eroded by almost every stronger storm. During the hurricanes which occurred in October of 1967, January of 1993, and December of 1999, the sea water burst through the dunes, flooded adjacent homesteads and even effused to the littoral plain (Žilinskas *et al.* 2001).

2. Methods

Topographic maps and ortophoto images collected from 1910 to 2010 were used for the comparative analysis of cartographic material (Table 1).

The characteristics of the changes in the Baltic Sea continental coastline were identified by comparing the digital coastline contour models from different years. These models were composed by digitizing printed maps with the help of ArcGIS 9.3 software module ArcMap. Statistical analysis of coastline contour of different years was performed using DSAS 4.2 software (Thieler *et al.* 2009). Comparative analysis of cartographic material reflects the peculiarities of coastline dynamics in time well; however it does not assess an important geoindicator, namely, coast silt changes. Due to this reason, the monitoring data collected since 1993 by the Sector of Coastal Research and Management of the Institute of Geology and Geography were also used in the analysis of Šventoji port area coastline dynamics.

An annual monitoring of coast condition in the area of Šventoji port is organized in 10 monitoring stations (5 northwards and 5 southwards from the southern jetty of Šventoji port). Locations of the stations are marked in Fig. 1.

The monitoring observations take place once a year in the first decade of June when the weather is calm, coast is relatively stable and the water level is close to the long-term average. The cross-profiles of the coast were levelled (using electronic tachometer TOPCON 229). Based on the measurement data, the changes of the shoreline, the crest and the foot of the foredune and the volume of sediments in the beach, in the foredune and in the coast in general (beach + foredune) were calculated. Extra observations were carried out after extreme storms: in December, 1999, after hurricane "Anatoly" and in January, 2005, after hurricane "Ervin".

Analysis of monitoring data showed that the present evaluation of coastal geodynamic trends is based on the best geoindicator: the surface sediment budget (m^3/m) or the sum of the temporal and spatial changes of eroded and accumulated coast composing material (calculated till the line of the long-term average sea level).

Table 1. Cartographic material used for the assessment of coastline dynamics

Map	Scale	Year
Maps of German Cartographical Service	1:25 000	1910
Maps of the USSR General Headquarters	1:25 000	1947
Maps of the USSR General Headquarters	1:10 000	1978
Ortophoto image	1:10 000	2010

The digital modelling to assess the possible effects of the port reconstruction on adjacent coasts in the future was employed as well. On 6 November 2003, the Strategic Planning Committee of the Government of the Republic of Lithuania established the following courses of underlying activities of Šventoji Seaport: service of recreational, small cruise and fishing vessels and service of boats of Būtingė Terminal. Reconstruction of the Šventoji port must be done to satisfy the needs of shipping. Some alternatives of reconstruction of Šventoji port jetties were proposed in (Feasibility study … 2009). Two main alternatives of reconstruction of Šventoji port were selected for modelling the impact of Šventoji port jetties on sea litodynamic processes (Fig. 2c). Alternative "1" (small port) consists of short jetties (length of 400 m), 6 meters of port depth, 7 m of design depth of entrance channel and channel direction from North-West. Alternative "2" (large port) consist of long jetties (length of 800 m), 6 meters of port depth, 7 m of design depth of entrance channel and channel direction from North-West. Alternative "0"is the present situation of the Šventoji port (Fig. 2b).

Numerical modelling method is used for evaluation of possible impact of planned reconstruction of the Šventoji port jetties on the coastal dynamics. The wave, hydrodynamic and sand transport processes were modelled using two-dimensional modelling system MIKE 21, more specifically: Near-Shore Spectral Wind-Wave (NSW), Hydrodynamic (HD) and Sand Transport (ST) models. Directions, periods and heights of waves in the surf zone have the biggest influence on lithodynamic processes of the Southeast Baltic. Model NSW (MIKE 21 2005c) defines the dispersion of wind-generated surface waves in the nearshore zone. The modelled wave parameters (period and height of wave) are used for modelling hydrodynamic and sand transport processes as the initial data in HD and ST models.

Hydrodynamic modelling was carried out for simulating wind- and wave-generated currents on the shoreface for different wind conditions. The unevenly changing flows of the two-dimensional model HD (MIKE 21 2005a) is the solution of equations of continuity and conservation of momentum. The water level variations and flows in the directions of the x and y axis in each modelled grid cell is the result of HD model.

In order to evaluate the sediment transport in the nearshore of the Baltic Sea, we used ST model (MIKE 21 2005b). It enables the calculation of the sediment transport rates and possible bottom changes (erosion and accumulation areas) caused by the flows and waves. Results of ST model are: unit discharge of sand transport (m^3/year/m) in any grid cell of a modelled area; discharge of sediments (m^3/year) in any section of modelled area; the bottom changes of modelled area (erosion and accumulation) per investigated period (m/day). During modelling of sediment transport (ST) it is necessary to define the average grain diameter in a sediment load and the grain distribution. According to (Galkus, Jokšas 1997) the average diameter of sediment grains in the Lithuanian nearshore is $d_{50\%} = 0.2$ mm.

Two bathymetries of the Baltic Sea nearshore are applied for evaluation of impact of Šventoji port reconstruction on the litodynamic processes: the Lithuanian Baltic Sea nearshore bathymetry (grid size for modelling – 100 m) and bathymetry of Šventoji port water territory (grid size for modelling – 20 m). The large grid bathymetry covers the whole water territory of Lithuanian Baltic Sea nearshore. This bathymetry is prepared for the extraction of boundary conditions for modelling of wave, hydrodynamics and sediment processes in Šventoji port water territory. The expanded bathymetry of Šventoji port water territory is created for possible detail layout structures of the port (it covers at least 5 km around port jetties).

3. Results

3.1. Analysis of cartographic material

The construction of Šventoji port in 1925–1940 significantly changed the processes of the coastline formation, as well as of the coastline condition from the Ošupis stream to the Latvian border. In the early 21st century, before the construction of the port, the coastline in the section was slightly convex and coast erosion tendencies prevailed. However, as soon as the works of the first construction stage were finished (in 1925–1926), silt began accumulating rapidly in Šventoji avanport, and filled the major part of it within only 10–12 years, leaving only a 3 m depth in its central part (Merkys 1934). Therefore, as mentioned previously, the construction of the long jetties began in Šventoji in 1939, bypassing the works planned for the second stage (Fig. 2a). Though the port construction was never finished, the constructed southern jetty to the depth of 7 m has been affecting the coastline dynamics significantly to the present day (Fig. 3).

By 1947, a cape protruding about 180 m to the sea, formed on both sides of the jetty. Its base length was about 870 m and its area was about 8.1 ha. Northwards from the cape, up to the Latvian border, the coastline has shrunk intensely: from 45–55 m in the central part of the section to 70–75 m in southern and northern parts. Coast erosion tendencies have also prevailed southward from the formed cape (except for two sections of approximately 400 m in length), where coastline has shrunk from 35 m in the northern part and 25 m in southern part to 65 m in the central part (Fig. 3).

Within the period from 1947 to 1978, in the light of intense sediment accumulation at the cape, area of the cape has increased over 4 times: from 8.1 to 35.1 ha. Sediment accumulation was especially fast in the southern part of the jetty, where the land area increased by 28.5 ha. The total length of the cape reached 5.65 km. It must be noted that even in the northern part of the cape with previously high wash-out levels, the coastline area has become stable (the northern part of the section) or even moved towards the sea (the southern and central parts of the section) (Fig. 3). Land area on the northern side of the southern jetty increased by 6.6 ha.

During the time period from 1978 to 2010, the accumulation tendencies on the southern side of the jetty remained, but the land increase intensity decreased (land area increased merely by 9.8 ha). About 300 m coastal section north of the jetty remained stable, and more northwards, coastline destruction prevailed.

Fig. 3. Coastline changes in the analysed area during the time period from 1910 to 2010

The comparison of land increase intensity from different time periods has shown that the most intense land increase in the analyzed area occurred during 1947–1978 (mean increase in 1.13 ha annually). From 1910 to 1947, the mean increase was 0.37 ha per year, and in 1978–2010, it was merely 0.30 ha per year. The period from 1947 to 1978 is also distinguished by silt accumulation northwards from the cape with the mean rate of 0.20 ha per year, meanwhile in the time periods of 1910–1947 and in 1978–2010, the coastline here was destructed at the rate of 1.20 ha per year.

It must be noted that a more significant effect of the unfinished northern jetty (approx. 120 m long) on the adjacent coastline dynamics has not been detected by the analysis.

Summing up the results of the cartographic material analysis (Fig. 4), it can be stated that the short jetties, constructed in 1925–1926, and the long southern jetty constructed in 1939 have caused an intense sediment accumulation in the port gate and southward. The port construction also caused the formation of the accumulative cape; the area of which has grown to 44.90 ha. Meanwhile, the coastline erosion processes have become especially intense northwards from the formed cape to the Latvian border. Approx. 38.41 ha area of land has been washed-out in the section. According to local residents, since the day the port construction was finished, the sea has taken about 17 residential buildings and outhouses in the above mentioned coastline section.

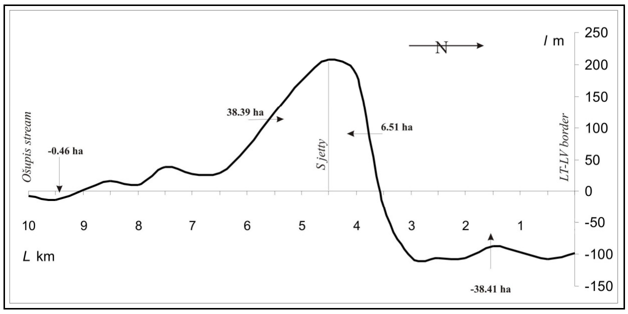

Fig. 4. Coastline changes in the area of Šventoji port from 1910 to 2010. 0 of X-axis identifies the coastline condition in 1910

3.2. Analysis of the coastline dynamics monitoring data

In course of time, the unattended and non-repaired jetties have been shortening and decomposing rapidly. The over-water part of the southern jetty of Šventoji port decreased from 780 m in 1939 to 495 m in 2010; its underwater part also decreased by 200 m. The unfinished northern jetty decreased by about 40 m (from 120 m to 80 m approx.) within the same time period. Thus, over the years, the jetties, especially the southern one, have become more and more pervious to sediments. The monitoring data collected during the last 17 years show sediment volume stabilization on the northern side of the jetty, and tendencies of accumulation in the southern part of the port (Fig. 5). Therefore, the coastline shrinkage intensity on the northern side of Šventoji port has been decreasing recently.

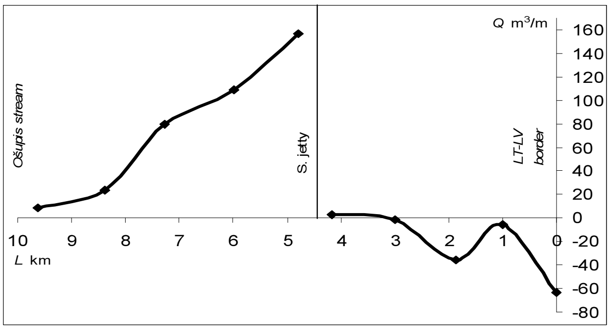

Fig. 5. Sediment changes (m^3/year) in the coastline section from the Ošupis stream to the Latvian border from 1993 to 2010

Coast cross-profile changes on both sides of the jetty are illustrated in Figs 6 and 7. The analysis of the coast cross-profile changes during the time periods from 1993 to 2002 and from 2002 to 2010 has shown that the first period on the southern side of the jetty is distinguished by a minor accumulation closer to the jetty (Fig. 6, profile 7), and erosion in the coastal section further from the jetty (Fig. 6, profile 10). Meanwhile, the tendencies of the last 8 years have changed: a significant accumulation is detected closer to the jetty. An embryo dune has begun forming in the section at the base of the foredune (Fig. 6, profile 7). Accumulation tendencies of much lower volumes are also detected in the uttermost south coastal section (Fig. 6, profile 10).

The coast cross-profile change tendencies on the northern side of the jetties are different. The coastline close to the jetty underwent more intense erosion in 1993–2002, while a minor accumulation was more prevalent during the time period from 2002 to 2010. Generally, the foredune has changed the configuration of its western slope without a significant change in sediment volume and coastline position (Fig. 7, profile 4). The erosion tendency in the uttermost north coastal section remained during both time periods, except that volumes of such erosion were greater in 1993–2002 than in 2002–2010 (Fig. 7, profile 1).

3.3. Numerical modeling results

An influence of reconstruction of Šventoji port jetties on the processes of nearshore bottom and sea coasts has been studied comparing the alternatives "1" and "2" with "0" alternative (Fig. 2c). A length of the port southern jetty of alternative "1" is 400 m, and of alternative "2" – 800 m.

The strong winds of rather long duration and permanent direction have the greatest influence on the processes of wave formation, hydrodynamics and sediment transport in the nearshore zone. We follow the classification that identifies winds with velocity above 15 m/s and below 20 m/s as intense winds, winds with velocity between 20 m/s and 25 m/s as stormy winds, and those above 30 m/s as hurricanes. The period of 1999–2010 was analyzed summarizing daily wind observation data from the Klaipėda coastal meteorological station. Southwest winds clearly dominate among strong winds: SW winds constitute 38.6%, W – 32.2% and NW – 11.0% each. Therefore, the sediment transport processes were modeled using the latter wind directions and the wind velocity of 20 m/s.

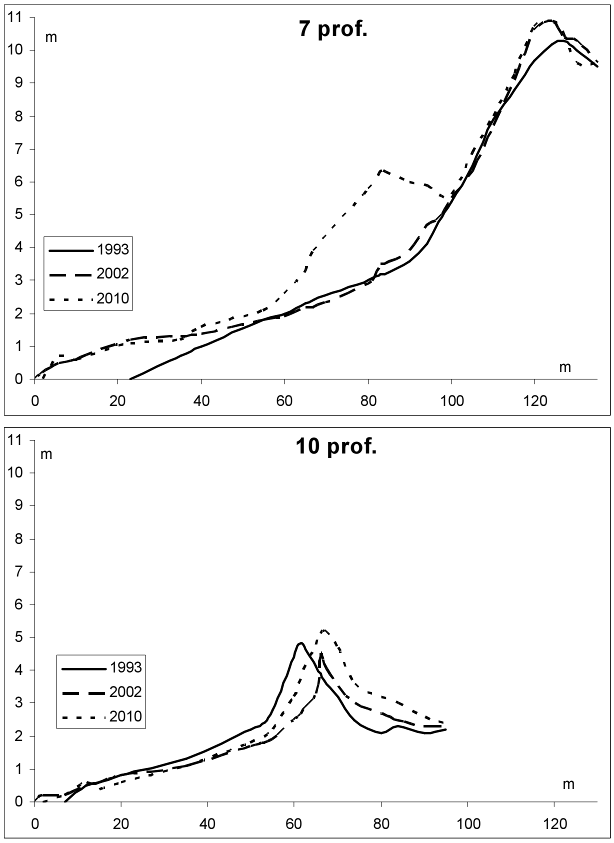

Fig. 6. Coast cross-profile changes to the south from the port jetties. Profile locations are marked in Fig. 1

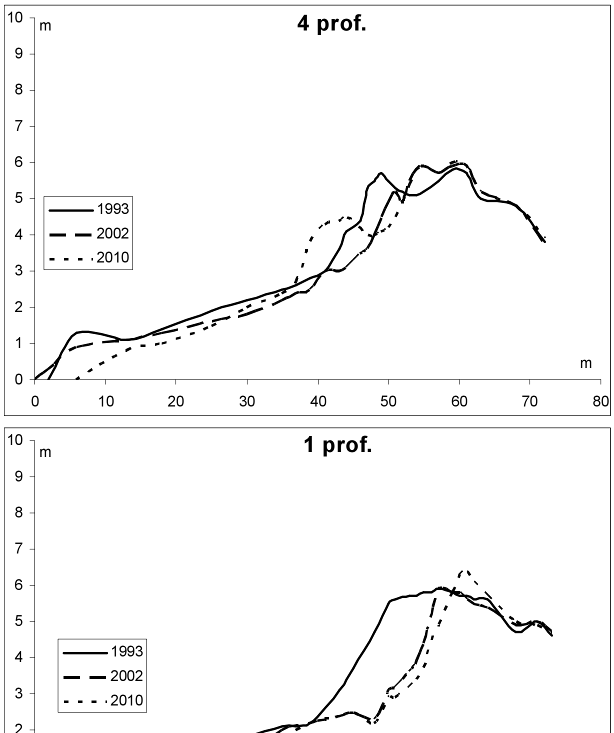

Fig. 7. The coast cross-profile changes to the north from the port jetties. Profile locations are marked in Fig. 1

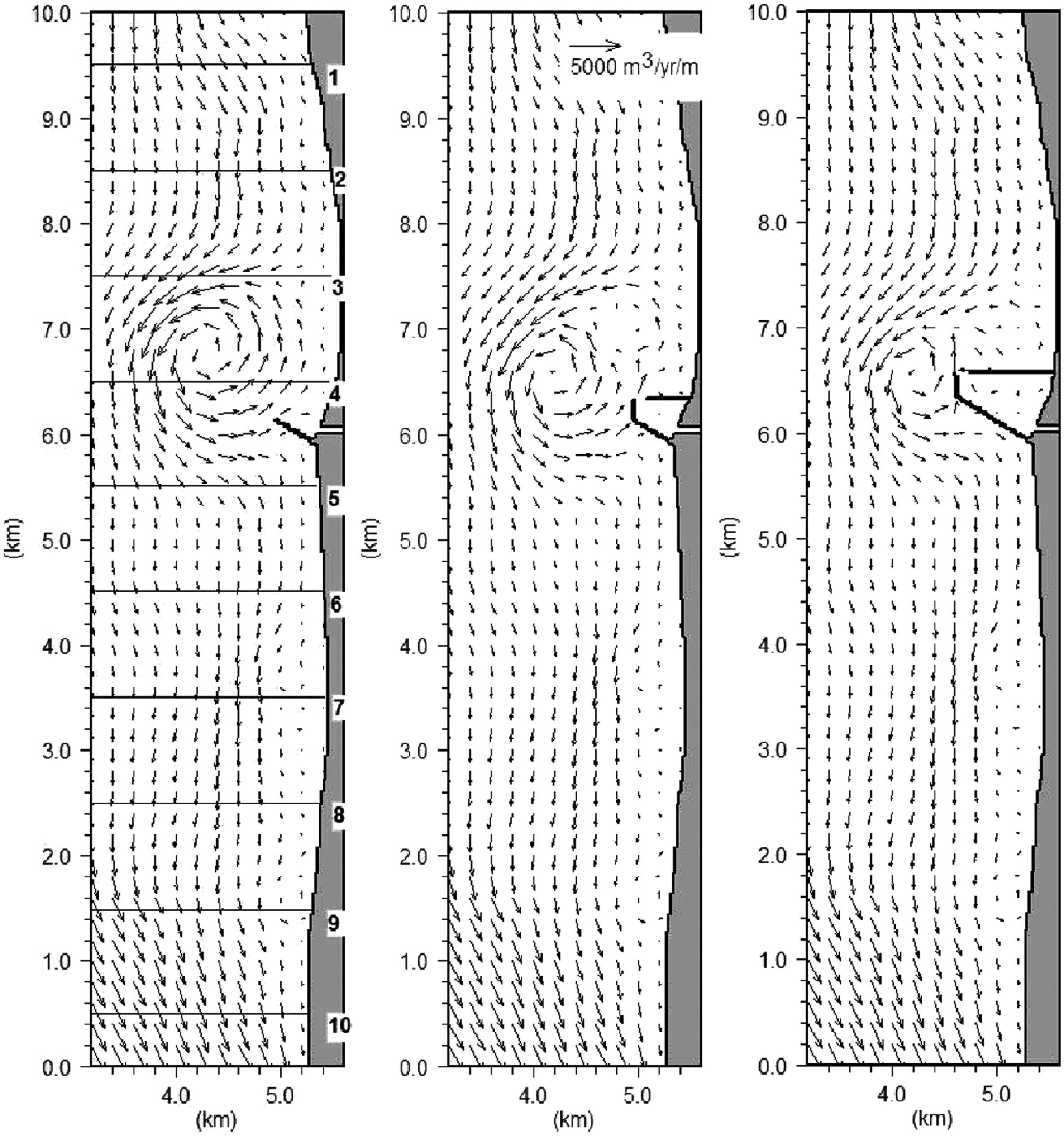

Fig. 8. Distribution of unit discharge of sediment transport (m³/year/m) blowing the wind of W direction of 20 m/s: "0" (a), "1" (b) and "2" (c) alternatives (calculation of sediment discharge was done for cross-sections from 10 to 1)

Modelling of the sediment transport allows us to examine the direction and magnitude of such processes, as well as define the areas of sediment erosion and accumulation. The distribution of unit discharge of sediment transport (m³/year/m) was calculated in water territory of Šventoji port for all alternatives and different directions of wind. Blowing the wind of W direction, the distributions of unit discharge of sediment transport are described in Fig. 8. There are some differences in the structures for "1" and "2" alternatives comparing with "0" alternative.

In order to identify areas of sediment erosion and accumulation, the nearshore of Šventoji port was divided into 10 cross-sections located 1 km from each other and perpendicular to the shoreline (Fig. 8). The south jetty of Šventoji port is located at the place of 4500 m between the 4th and 5th cross-sections, the 10th cross section – the Ošupis stream and the 1st cross-section – 1 km from LT-LV border. Each cross-section extends from the open sea (water depth to 16 m) to shoreline. Sediment transport rate (m³/day) was calculated for each section. The period of one day was chosen because the average duration of a storm in the Lithuanian nearshore is approximately 25 hours.

Fig. 9 shows the distribution of sediment discharges (m³/day) for "0", "1" and "2" alternatives under strong winds of different directions, which are the most important for sediment transport. Positive transport (sediments being carried to the South) is observed for the W and NW winds, while negative transport (sediments being carried to the North) occurs with the winds of SW direction. The biggest quantities of sediment are carried with the winds of SW and NW directions and the lowest ones – with W winds.

In Fig. 9 the rising segments (increasing of sediment discharge) of the curves indicate bottom erosion in the appropriate cross-sections and the falling parts (decreasing of sediment discharge) – the opposite process, sediment accumulation. The peaks (representing both local maximums and minimums) of the curves identify the changes from the accumulation areas to erosion zones or vice versa. Blowing the wind of W direction (Fig. 9b), the similar near-shore places of accumulation (from 10 km to 4 km) and erosion (from 4 km to 1 km) were determined for all alternatives. Only the difference of sediment discharge in the cross-sections from 10 km to 4 km are less for "2" alternative than for "0" and "1" alternatives. It means that bigger sediment accumulation will occur in this area according to "0" and "1" alternatives. Similar erosion processes will occur in the nearshore area from 4 km to 1 km for "0" and "1" alternatives. Only erosion will be less for "2" alternative.

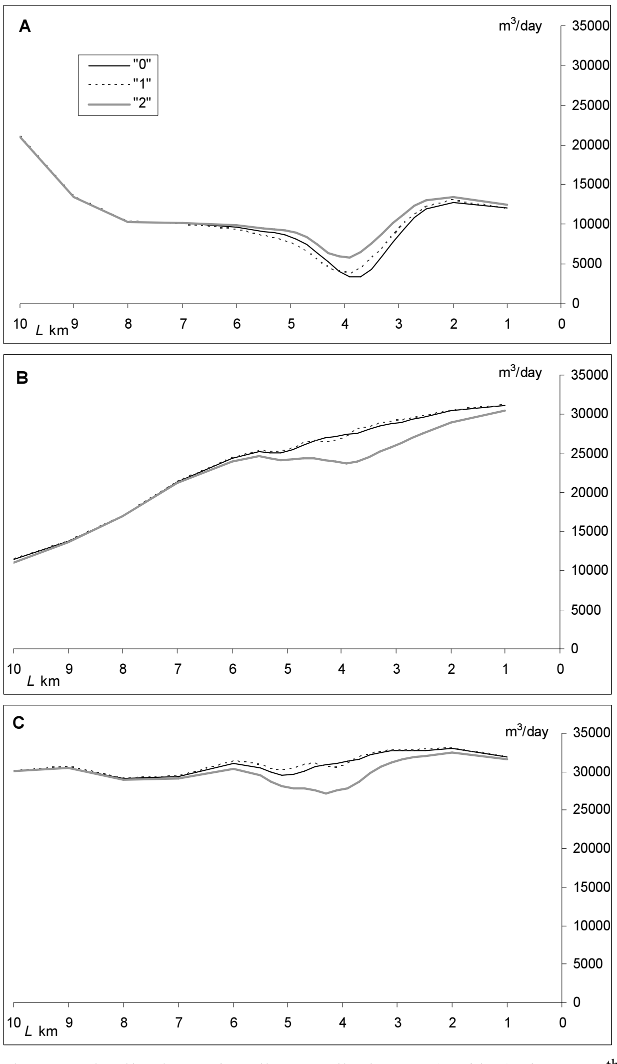

Fig. 9. Distribution of sediment discharge (m³/day) from 10th cross-section (the Ošupis stream) to 1st cross section (1 km to LT-LV border) for "0", "1", and "2" alternatives blowing wind of NW (A), W (B) and SW (C) directions

Blowing the wind of NW direction (Fig. 9a), bigger erosion process will be in the nearshore from 4.2 km to 2 km for "2" alternatives than for "0" and "1" alternatives. Blowing the wind of SW direction (Fig. 9c), the erosion processes will be in the nearshore from 10 km to 5.5 km for all alternatives. Smaller erosion rates will be from 5.5 km to 1 km for "0" and "1" alternatives. Bigger erosion will occur from 3.6 to 1 km for "2" alternatives.

There are two groups of similar sediment discharge curves (Fig. 9): in one group the curves for "0" and "1" alternatives and in the second group - for "2" alternative. It means that the reconstruction of Šventoji port according to "1" alternative will change the present state of sediment transport the least comparing with "2" alternatives.

The reconstruction of Šventoji port according to "1" alternative answers the minimal requirements of port and makes the least impact for the hydrodynamic and lythodynamic processes in the Baltic Sea nearshore. The reconstruction of port according to "2" alternative will cause the bigger erosion processes northwards from the port jetties.

Conclusions

1. Summing up the results of the cartographic material analysis, it can be stated that the short jetties, constructed in 1925–1926, and the long southern jetty constructed in 1939, have caused an intense sediment accumulation in the port gate and southward. The port construction also caused the formation of the accumulative cape; the area of which has grown to 44.90 ha. Meanwhile, the coastline erosion processes have become especially intense northwards from the formed cape to the Latvian border. Approx. 38.41 ha area of land has been washed-out in the section.

2. Thus, over the years, the southern jetty has become more and more pervious to sediments. The monitoring data collected during the last 17 years show sediment volume stabilization on the northern side of the jetty, and accumulation in the southern part of the port tendencies. Therefore, the coastline shrinkage intensity on the northern side of Šventoji port has been decreasing recently.

3. Results of sediment transport modelling confirm that the reconstruction of Šventoji port according to "1" alternative (length of jetties – 400 m) answers the minimal requirements of port and makes the least impact for the hydrodynamic and lithodynamic processes in the Baltic Sea nearshore. The reconstruction of port according to "2" alternative (length of jetties – 800 m) will cause more significant erosion processes northwards from the port jetties.

4. Due to the fact that the reconstructed Šventoji port is going to be located almost in the same place, and its planned parameters (jetty length, aquatory depth, etc.) resemble the ones of the old port, the tendencies of the coastline dynamics in adjacent regions should be similar to the ones discussed in the paper (i.e., should resemble the ones that were prevalent previously). The intensity of the coastline dynamics may differ for different alternatives of port reconstruction.

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