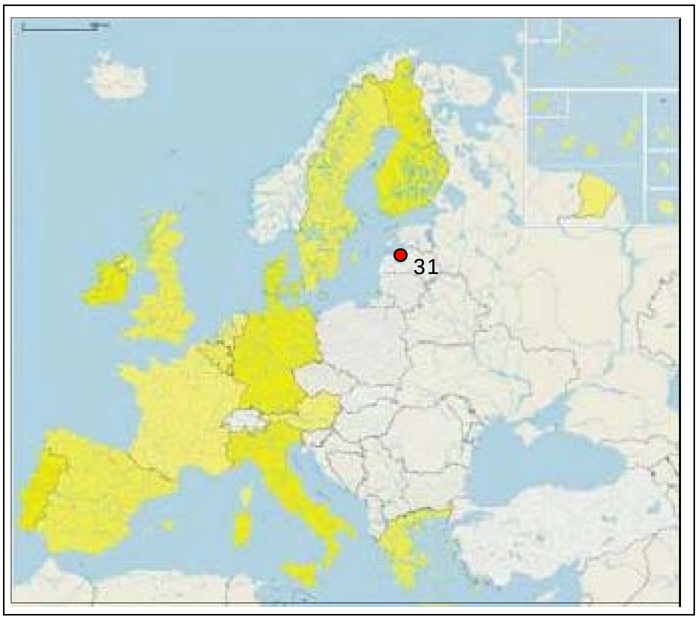
GULF OF RIGA
(LATVIA)



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1. GENERAL DESCRIPTION OF THE AREA

The length of the Latvian coastline along the Baltic proper and the Gulf of Riga is 496 km. Circa 123 km of the coastline is affected by erosion. The case area '*Gulf of Riga*' focuses on coastal development within the Riga metropolitan area, which includes the coastal zone of two urban municipalities (*pilsetas*) – Riga and Jurmala (*Figure 1*).

Riga is the capital city of Latvia. It is located along the lower stream and the mouth of the Daugava river. Its several districts (Bulli, Daugavgriva, Bolderaja, Vecdaugava, Mangali and Vecaki) lie in the deltas of Daugava and Lielupe rivers and on the Gulf of Riga coast. Jurmala municipality is adjacent to Riga from the west. It stretches ca. 30 km along the Gulf of Riga. It is the largest Latvian and Eastern Baltic seaside resort.

1.1 Physical process level

1.1.1 Classification

According to the coastal typology adopted for the EUROSION project, the case study area can be described as:

3b. Wave-dominated sediment. Plains. Microtidal river delta.

Within this major coastal type several coastal formations and habitats occur, including the river delta and sandy beaches with bare and vegetated sand dunes.

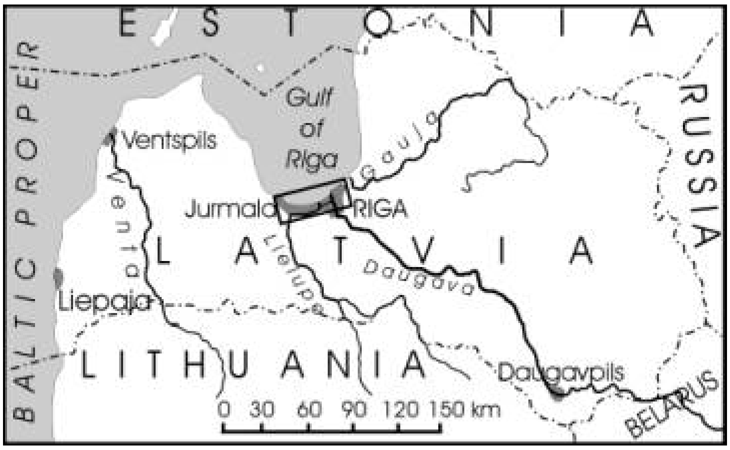

Fig. 1: Location of the case study area.

1.1.2 Geology

Recent geological history of the case area since the end of the latest Ice Age (ca. 10 – 12 thousand years B.P.) is closely related to the development of the Baltic Sea. The transgression of the sea after the deglaciation caused active erosion of Quarternary glacial deposits and longshore sediment distribution.

The key processes featuring the latest geological and geomorphological development of the coastal region in and around the study area were the formation of dune ridges, lakes and wetlands after the Littorina transgression (5 – 6 m above the modern sea level) in the mid-Holocene (8 – 5 thousand years B.P.), as well as the later rapid growth of Daugava and Lielupe river deltas. Hence the modern coastal zone of the study area presents a wide flat accumulative plain intersected by rivers, lakes, wetlands and dune ridges. The prevailing sediment type of the coastal zone within the foreshore, beach and dunes of the study area is fine to medium-sized quartz sand (M_d=0.1 – 0.2 mm).

1.1.3 Morphology

The morphological features of the study area show that Jurmala – Riga region represents a graded and flat coastal area. It has a shape of two concave arcs, which are intersected by the mouth of Daugava River (Figure 4). Jurmala – Riga coast is characterized by 40– 60 m wide sandy accretion beaches, which gradually descend into morphologically similar sandy foreshore (i = 0.003). Up to 3 shore-parallel underwater sand ramparts feature the flat foreshore of this area. The onshore part of the sedimentary coast is framed by the artificially created 3 – 6 m high foredune behind the beach. Behind the modern foredune there is an ancient 8 -15 m high dune ridge left after the Littorina sea transgression. The landscape of Lielupe and Daugava deltas is typical for the deltaic lowland where coastal marshes and meadows are interspersed by deltaic branches, oxbow lakes and dunes.

1.1.4 Physical processes

Waves and storm surge

Wave activity and the wind-induced surge during storm events are the principal physical erosion agents in the study area. A relatively short wave fetch over the shallow Gulf of Riga limits the wave energy reaching the study area. The highest waves are 1,8 – 2,5 m high only. However the concave and flat coast of Jurmala and Riga is exposed and extremely susceptible to the storm surge caused by the north and northwest storms, raising the water level up to 1 – 2 m at the mouth of Daugava. Annually there are about 25 – 40 stormy days with the wind velocity above 15 m/s in the study area.

Particularly negative impact on the shoreline development in the second half of the 20th century was caused by the combined effect from the increasingly frequent storm surge events, and from the increasing water discharge from Lielupe and Daugava rivers into the Gulf of Riga during the autumn-winter season. Such combination has led to the disastrous increase of the mean sea water level at the mouth of Daugava River (up to 20 cm in the second half of the 20th century, see Figure 2 and Figure 3).

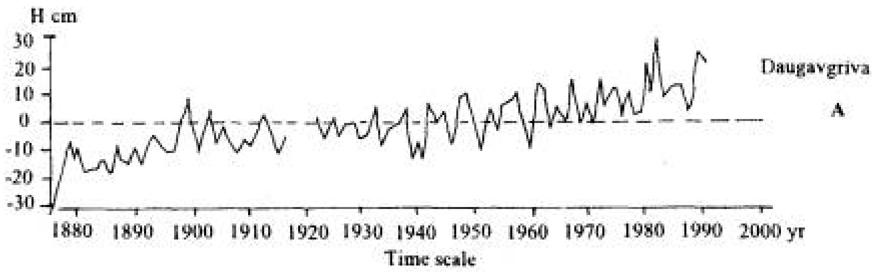

Fig. 2: Time series of annual mean water level in Daugavgriva (Eberhards & Saltupe, 1996).

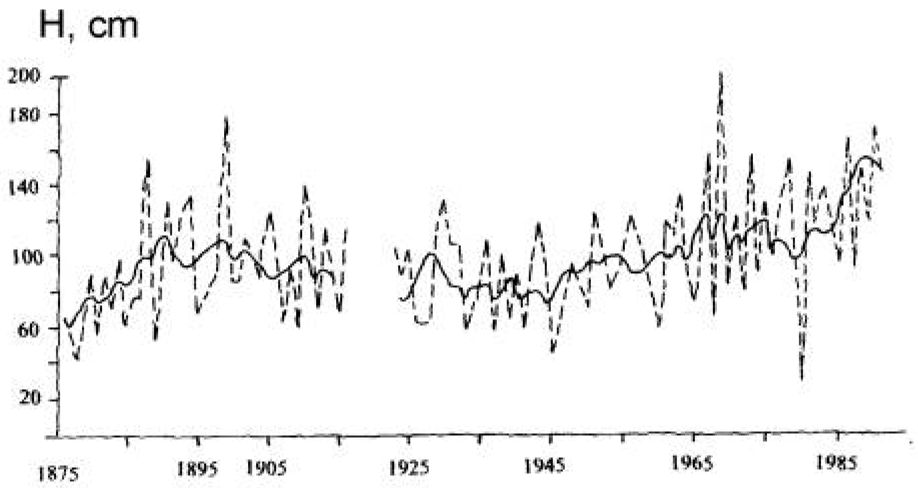

Fig. 3: Time series of annual high water level in Daugavgriva (Eberhards & Saltupe, 1996).

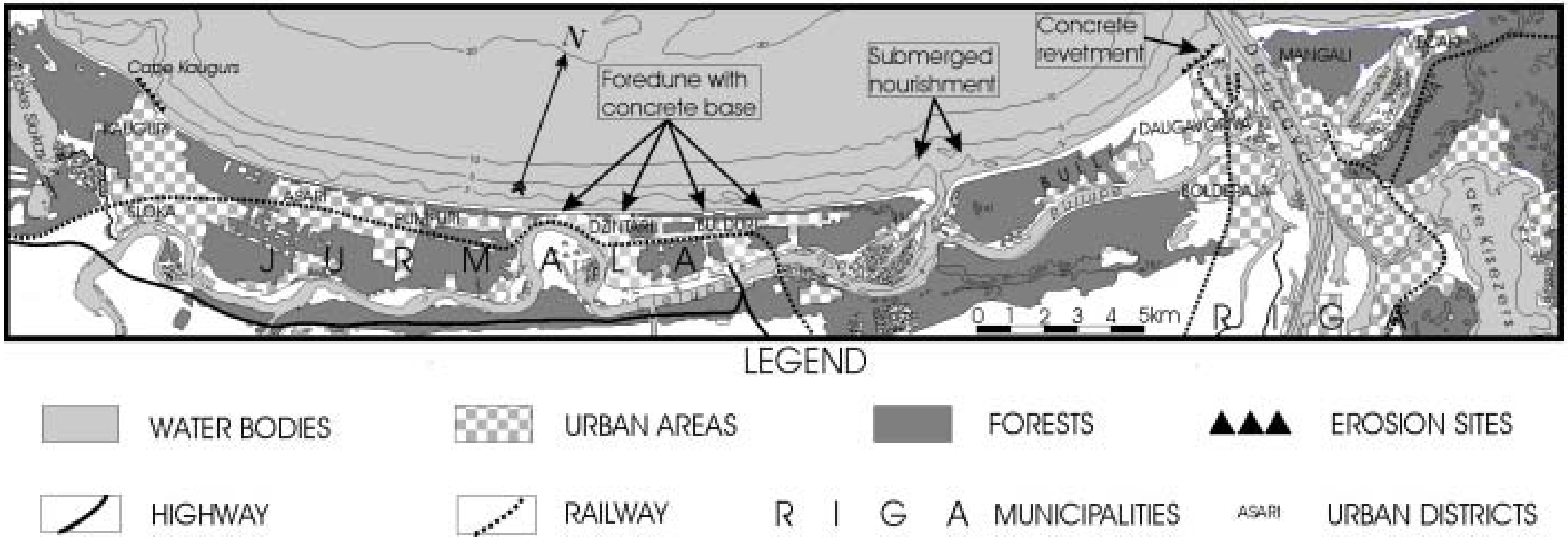

Fig. 4: Map of Riga – Jurmala case study area.

Ice

In winter an ice cover develops in the Gulf of Riga, although not every year. A steady ice cover puts an end to wave action for the winter period but in spring when the increasing water level raises the ice, the ice-sheet breaks up and is pushed on to the coast by strong winds, where it piles up in 5 – 10 m high hummocks. Ice, which is pushed on to the shore, damages the coast (beach and dunes). Whatever strong ice pile-up might be so far it had only a very limited long-term impact on coastal development within the study area, as the spatial distribution of ice-scours randomly varied with every event. Yet the combination of ever more frequent disastrous wind-induced water level rise in the foreshore with ever-higher winter- and/or spring-flood events at the river mouths might cause an ever-increasing threat from ice pile-ups upon the coast.

Decline of sediments

Since the 30's of the 20th century the construction of the cascade of dams on the Daugava river and dredging of sand for construction purposes from the Lielupe lower stream has essentially reduced the amount of river sediments reaching the Gulf of Riga, and caused the deficit of sediment output feeding the foreshore and beaches. This deficit in its turn has enhanced the coastline retreat in the areas adjacent to the Daugava river mouth in the end of the 20th century.

Eustasy vs. Isostasy

The south coast of the Gulf of Riga is in a tectonic equilibrium with resulting insignificant movements of the Earth's crust, which have negligible impact on secular coastal development in the study area.

Tide

Regular tide ranges in the adjacent Baltic Sea foreshore are less than 0.25 m; therefore tidal action plays virtually no role in coastal development.

Weathering and underwashing

Impact is possible at cape Kaugurs, which is an eroded residue of a coastal dune formation overtopping the Palaeozoian sandstone bedrock.

1.1.5 Erosion

The resulting direction of the secular sediment drift along the western coast of the Gulf of Riga is southward – from the eroded bluffs of Kurzeme highland towards the mouths of Daugava and Lielupe rivers. The estimated net sediment transport rate is app. 25 thou. cub. m annually (Figure 5).

Structural erosion

In a secular time span the coastal stretch of Jurmala and Riga is close to the dynamic equilibrium conditions with prevailing slight accretion.

Acute erosion

The last two decades witnessed a certain change of dynamic equilibrium conditions in coastal development of the study area. The activation of coastal processes has been observed along the entire coastline. As it has been already mentioned above, such increase in coastal erosion is triggered by the increasing frequency of the extremely strong and disastrous storms of the western and northern fetches combined with the wind-induced sea level rise. Particularly strong coastline erosion and recession in the last decade occurred during extremely strong storm events of 1992 and 2001, which usually occur only once in a hundred years. Erosion rates of 20 to 30 meters during a single storm event have been recorded in the study area. Also, direct human impact should be considered as well, e.g., reduction of sediment input from Lielupe and Daugava rivers, construction of breakwaters in the mouth of Daugava etc.

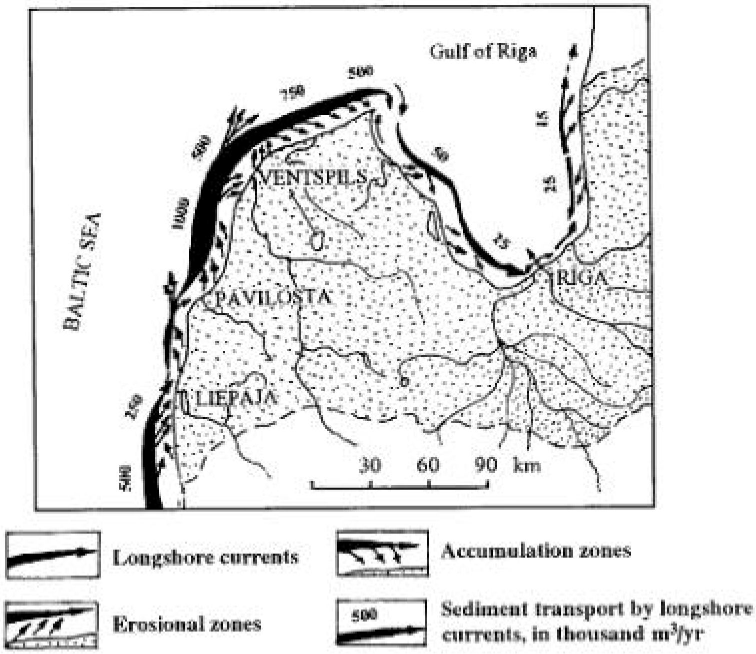

Fig. 5: Resulting secular longshore sediment drift, erosion and accretion zones of Latvian coast (Eberhards & Saltupe, 1996, after Knaps, 1966).

1.2 Socio-economic aspects

1.2.1 Population rate

The total number of people living in Jurmala and coastal districts of Riga is ca. 80 thousand. The number of inhabitants per square kilometre is ca. 400 – 600.

1.2.2 Major functions of the coastal zone

- **Tourism and recreation:** As it has been already mentioned above, Jurmala is the biggest eastern Baltic seaside resort and spa, therefore tourism and recreation plays the principal role in the development of the study area. Up to 10 Million tourists visit Jurmala annually.

- **Conservation:** The study area is very important for conservation of cultural and natural heritage as well. Daugavgriva fortification (17th century) is protected as a historical monument, coastal forests and dunes of the study area, being the integral part of the coastal protective belt, enjoy protection within the general nature conservation framework. There are quite a few nature reserves and nature parks in Jurmala and in the coastal zone of Riga (Table 1).

Table 1: Protected nature areas in the coastal zone of Riga and Jurmala (Source: Riga and Jurmala City Councils).

Name	Protection status	Size (ha)	Main biotopes
Piejuras	Nature park	1283	Deltaic islands, coastal forests, foredune, forested dunes and dune slacks
Vakarbullu	Nature reserve	58	Reed and bulrush beds
Daugavgrivas	Nature reserve	113	Reed and bulrush beds
Vecdaugavas	Nature reserve	236	Reed and bulrush beds
Ragakapa	Nature reserve	84	Coastal forests and dunes, foredune and dune slacks

- **Industry, transport and energy:** The turnover of the Riga Port was 14.89 Million metric tons of cargo in 2001. The composition of cargo is the following: timber - 29%, oil products – 23%, fertilizers – 10%, coal – 8%, various metals – 7%, containers – 7%, wood chips – 4% and other cargo – 12%. The harbours within the mouth of the Daugava river are specializing in handling of timber, oil and fish products. Data about the turnover of each particular harbour are not available. The Bolderaja ship repair yard is currently closing down, while its territory is designated for a new oli terminal (a projected turnover 2.5 Mio. metric tons of oil products annually). Riga municipal wastewater treatment plant is located on Bullu Island. It serves the needs of the entire metropolitan area (ca. 125 Mio cub. m of wastewater treated annually).

- **Urbanisation (safety of people and investments):** Ca. 55 thousand inhabitants dwell in Jurmala municipality and ca. 25 thousand – in the coastal districts of Riga. These latter are particularly vulnerable regarding the flooding during the storm surge events (ca. 5 thousand inhabitants potentially threatened).

- **Fisheries and aquaculture:** Lielupe river mouth provides port facilities for the small-scale fisheries. Technical characteristics are the following: the number of wharves is 4, length: 76 – 103 m, depth: 3.0 – 4.8 m. There is no aquaculture of an industrial scale in the study area.

- **Agriculture and forestry:** No agriculture and forestry of an industrial scale is in this predominantly urban area. Agricultural activities are mostly cultivated in small-scale gardening colonies while forests mainly serve for recreational and conservation purposes.

1.2.3 Land use

The land use at the case area is shown in Figure 4. Land use in the Gulf of Riga is characterized by forests alternated with urban areas. Forestry covers about 70 % of the coastal strip, urban areas and industry cover the rest of the land.

1.2.4 Assessment of capital at risk

Within the study area the increasing erosion currently threatens the recreational functions of the Jurmala beaches and the existence of up to ten ancient villas, which are located too close to the eroded foredune and beach (Fig. 3). As this is one of the most prestigious residential area and the most visited seaside beach in Latvia, the total capital at risk could be valued ca. 2 – 3 Mio EUR. The costs for the mitigation of losses inflicted by the November 2001 storm to the coastal zone of Jurmala municipality are given in Table 2.

Table 2: Costs for the mitigation of losses inflicted by the November 2001 storm to leisure facilities in Jurmala (Source: Jurmala City Council).

Item	Unit	Quantity	Costs (EUR)
Handling of beaches	km	22	2’180
Restoration of access roads	gateways	7	1’340
Restoration of drainage network	outlets	7	120
Revegetation of foredunes	km	16	22’460
TOTAL			26’100

2. PROBLEM DESCRIPTION

2.1 Eroding sites

The eroding sites can be seen in Figure 2, and are described below (from west to east):

- **Coast of Jurmala**

Cape Kaugurs: coastal retreat rate was ca. 1 – 2 m annually in the 90's of the 20th century. Waves erode coastal sandy cape overgrown with pines.

- **Coast of Riga**

Daugava mouth (left side): coastal retreat rate was ca. 1 – 1.5 m annually in the 90's of the 20th century. Wind surge and waves erode the coast adjacent to the western breakwater of the Daugava river mouth at Daugavgriva. In November 2001 the storm surge has totally washed away the 100 m long strip of the foredune (Figure 6) and the storm water has flooded into the coastal wetland.

Fig. 6: Erosion site where the storm surge broke through the foredune in November 2001 in Daugavgriva. Photo: R. Povilanskas, December 2002.

Fig. 7: The concrete base of the foredune, erected after the storm of 1969 and exposed again after the erasure of the foredune in November 2001. Photo: G. Eberhards, November 2001.

In other places, particularly in the central part of Jurmala seaside resort the coast is affected only during the extremely severe storms (the last ones in 1992 and 2001). Whether or not the coastline will tend to retreat in the longer time-span is the matter of frequency of such disastrous events.

2.2 Impacts

In the long term the major threat caused by erosion is related to the degradation of the beach and the foredune on a relatively wide coastal span. Coastal erosion already poses threat to the houses adjacent to the foredune in Jurmala and, eventually, to the harbour facilities at 'Ziemas osta' in Daugavgriva. In other districts of Jurmala and Riga only some property or infrastructure is threatened directly by coastal erosion (Figure 8). However since the study area is very important for recreation, the increasing erosion of the beach and the foredune might eventually threaten leisure facilities, which are the closest to the seacoast (Figure 9).

Fig. 8: Temporary defence measures in the place of the washed-off foredune. Jurmala, November 2001. Photo: G. Eberhards, November 2001.

Fig. 9: Exposed recreation facilities after the storm surge erased the foredune.Jurmala, November 2001. Photo: G. Eberhards, November 2001.

3. SOLUTIONS/MEASURES

Fig. 10: The revetment of Daugavgriva exposed after the storm of November 2001. Photo: R. Povilanskas, December 2002.

3.1 Policy options

The most opted coastal protection policy in Latvia in general and in the case study area in particular is limited intervention through coastal forest and foredune management, as well as through the submerged nourishment aimed to stabilize the coastal zone, particularly the recreational beaches. As it has been mentioned above, the foredune is maintained behind the beaches at nearly the entire length of the case study area. Coastal pine plantations cover the dune ridges and other locations on 80% of the coast length. At Daugavgriva the continued coastal management policy is to hold the shoreline in order to protect the Riga port facilities.

3.2 Strategy

Limited intervention

To fight coastal erosion, all forests and foredune ridges of the coastal zone in the case study area have been classified as protected and preserved. The Forestry Department (Ministry of Agriculture) is responsible for policy making, legislation, and coordination of practical efforts. However, there is a lack of financial resources available. The Law on Protected Belts (1997) gives several restrictions for land use in the coastal zone. It defines a protection belt of 300 m, starting from the permanent vegetation line, and also extending 300 m seaward from the permanent vegetation line including the beach. If the dune or other coastal formation exceeds 300 m, the protected zone is extended to its natural boundaries. In this zone any new construction is prohibited. The law also defines a belt of 5-7 km with limited economical activities. Unfortunately, the law is not always respected, particularly, in Jurmala municipality.

Local authorities have to maintain protected natural areas. They have rights to elaborate the regulations on the use of protected coastal territories in co-ordination with Regional Environmental Boards. The National Programme for Biological Diversity (1999) considers problems of environmental protection - including ecosystems like the Baltic Sea, Gulf of Riga, beaches, dunes and coastal lakes - with potential economic solutions.

Hold the shoreline

Since the 1960s the efforts are made to protect the facilities of the '*Ziemas osta*' (*the Winter harbour*) in Daugavgriva from erosion (Figure 10).

3.3 Technical measures

Type

➢ **Foredune and forestry maintenance**
As was mentioned, maintenance of coastal foredune and forest plantations is the principal technical coastal stabilization measure within the study area. In central part of Jurmala there was a concrete seawall erected as a base for a newly raised foredune after the storm of 1969 (Figure 7).

➢ **Revetment**
The revetment of Daugavgriva was built in 1960s in order to protect the adjacent port facilities from erosion. There was a dike (a storm surge barrier) established and a concrete revetment was built in front of it. In 1999 the revetment has been reconstructed by applying geotextile technology.

➢ **Submerged nourishment**
Sand material dredged from the Lielupe river has been applied for the submerged nourishment of the coastal zone in 1990s in the foreshore adjacent to the river mouth.

Technical details

➢ **Foredune and forestry maintenance**
Pine forest plantations are managed through cleaning, selective cutting and replanting. Foredune is maintained by fastening and revegetation techniques. The marram grass and the willow are the most commonly applied plant species for the foredune revegetation.

➢ **Revetment**
The length of the revetment in Daugavgriva was ca. 600 m.

Table 3: Amount of dredged material in the mouth of Lielupe river (Source: Latvian Marine Environmental Board).

Year	Amount in m^3
1998	43000
1999	36000
2000	22000
2001	18000

➢ **Submerged nourishment**
The amount of dredged material (fine sand and silt) applied for the submerged nourishment at Jurmala foreshore is given in Table 3. The depth at which the dredged sediments were dumped is 4 m.

Costs

➢ **Foredune and forestry maintenance**
Annual maintenance cost for coastal pine forests is 3,0 thousand EUR per hectare. Annual maintenance costs for coastal foredune is 1.5 thousand EUR per hectare.

➢ **Revetment**
Revetment building costs from the Soviet period are incomparable with modern market-related costs of material, labour and technologies. The revetment reconstruction costs in 1999 were in the range of 100 – 200 thousand EUR.

➢ **Submerged nourishment**
The costs of the submerged nourishment were in the range of 2 – 2.5 EUR per cub. m of dredged and nourished material, which made the total cost of this measure 240 – 300 thousand EUR during the period of 1998 – 2001.

3.4 Issues concerning threat to life and property

There exist detailed evacuation plans for a flooding (storm surge) period in the case study area. However the distribution of tasks and functions for the implementation of these plans is rather complicated. Three public agencies are responsible for the emergency mitigation of erosion and/or flooding disaster effects and for evacuation of people: municipal civil defence and fire defence offices of Riga and Jurmala, as well as the Coastal Guard of Latvia.

Most of the expensive houses in the coastal area of Riga and Jurmala are insured against damage. In the case of a very big eventual flooding or erosion disaster the municipalities are supposed to provide a limited subsidy for those who would suffer the most. For the bigger aid or for compensation of the mitigation costs, like in the case of November 2001 disaster, municipalities apply to the national Government.

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

The November 2001 disaster proved that erosion didn't stop in spite of any measures applied throughout decades. The revetment of Daugavgriva has been destroyed along with the foredunes.

4.2 Effects related to socio-economic aspects

Any chosen strategy worked to maintain the key socio-economic functions of the coast until the very first extremely strong storm event. Then all socio-economic functions have been undermined and it will take several years to restore them at full scale.

4.3 Effects in neighbouring regions

The limited intervention (forest and dune management and the submerged nourishment) has played a positive effect in neighbouring coastal regions, while the construction and desperate efforts to maintain the revetment at Daugavgriva have (presumably) triggered the extensive beach erosion and the breakthrough in the foredune in the adjacent area during the November 2001 disaster.

4.4 Relation with a ICZM

Coastal beach, dunes and forests in the study area enjoy a comprehensive protection within the 5 – 7 km wide coastal protection belt. Riga and Jurmala municipalities have approved their spatial development plans, which in coastal zone follow the key ICZM principles. However in practice coastal management in Latvia suffers from legislative and constitutional problems. Conflicting legislation between, and within sectors and a lack of communication between various levels of gouvernment results in failure of new legislation to amend or repeal existing legislation, and creates overlap and conflicts in interest between agencies at all levels of management. Financial issues undermine effective coastal management, rendering local governments under-funded and there is lack of qualified manpower and capacity for adequate plan preparation on several levels of local government. The lack of a National Spatial Plan is a problem for ICZM and spatial planning.

An international ICZM project for the Baltic States and Poland (1998 – 2000) also covered the study area. This satellite-image and GIS (Geographic Information System) based project was aimed to give Estonia, Latvia, Lithuania and Poland the opportunity to better manage their coastal resources in an environmental and sustainable way.

4.5 Conclusions

Effectiveness

As was already mentioned above, the November 2001 storm has undermined the illusion that any coastal protection measures could prevent the erosion. Apparently the Latvian coasts, particularly in the study area, face the challenge unseen in the last centuries: if the frequency of the extremely strong storms of the northwest fetches increases, then these formerly stable coasts might witness a dramatic decline in the next decades.

Possible undesirable side effects

The only undesirable side effect is the above-mentioned extensive beach erosion and the breakthrough in the foredune in the adjacent area of the Daugavgriva revetment during the November 2001 storm. In the conditions of the increasing storm activity any future interventions into the coastal zone should be considered very cautiously. Meanwhile there are plans to build a new large oil terminal in Daugavgriva (instead of Bolderaja ship repair yard). This construction will certainly include ‘hard’ coastal defence measures instead of the former revetment. Such intervention into the coastal zone might be fatal to the beaches and the foredune at Daugavgriva.

Gaps in information

There is an apparent shortfall in the exchange of information related to coastal management among public institutions. There is not a single institution in Latvia, which contains a coherent picture of what is going on in the coastal zone of that country, or possesses all relevant information, which were important for sound and integrated decision-taking related to the coast. E.g., although the geographers at Latvian University have a rather long monitoring record of coastal dynamics in Latvia, they are seldom asked for advise regarding coastline management, while those private or semi-public companies who take active efforts in coastal development and defence almost never share their knowledge with public institutions and authorities.

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