Case study: Gulf of Riga (Latvia)

Technique: Beach nourishment

Location

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 (Fig. 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.

Fig. 1: Location of the coastline of Latvia and the case study area, including harbours, main rivers, and direction of integral load transport. (http://www.paic.lv/en/problemas_2.php)

Coastal morphology and dynamics

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 2). 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.

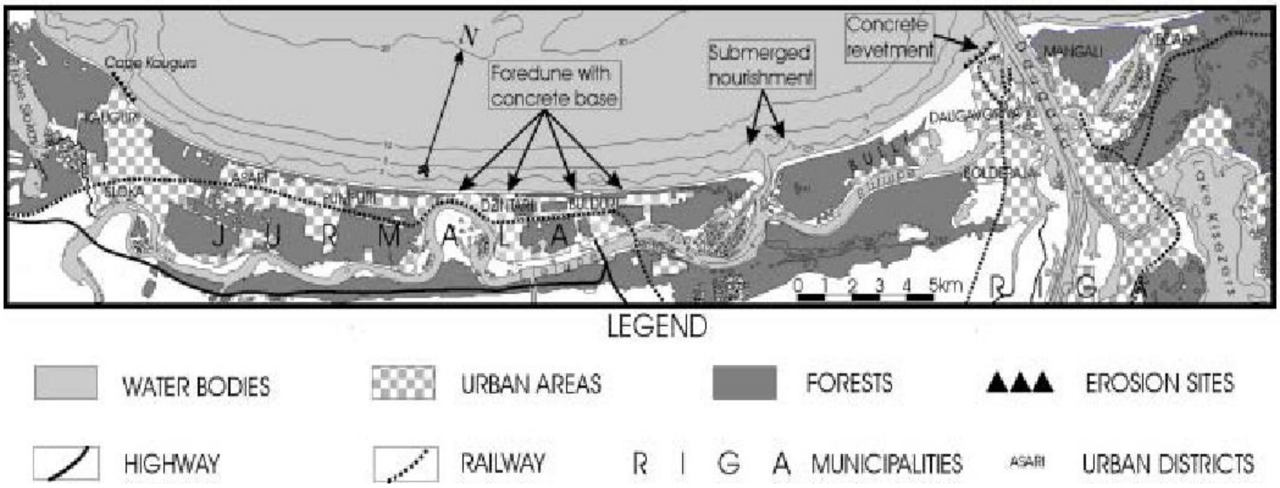

Fig.2 : Study area. Source: Shoreline Management Guide Eurosion case study Gulf of Riga, at: http://www.eurosion.org

The principal dynamics processes involved in the case study area are:

- *Waves and storm surge:*
  Wave activity and the wind-induced surge during storm events are the principal physical erosion agents in the study area. The concave and flat coast of Jurmala and Riga is exposed and extremely susceptible to the storm.

- *Ice:*
  Sometimes, in winter, an ice cover develops in the Gulf of Riga, 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.

- *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.

- *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.

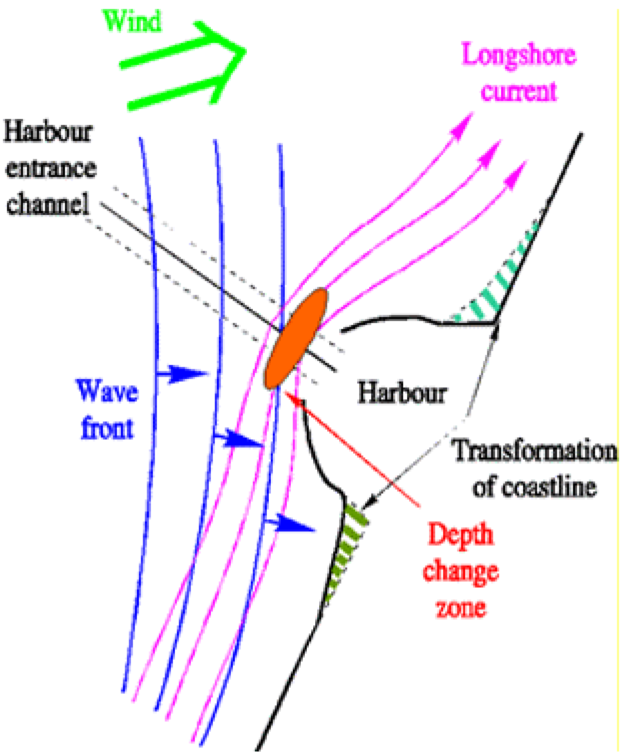

Fig.3. Scenario of development of the coastal load transport processes.

The principal scheme of the processes related with the along-shore sediment transport and their interaction began when the bed and suspended load transport is driven by the coastal hydrodynamics. The alongshore and **wind** currents determine the velocity and orientation of mainly longshore load transport that have maximum values at the depths of about 0 to 7 m. **The wave field**, especially in the zone of breaking waves, is the most important generating the shear-stress and producing the suspension of the grain material in the water column. Wave-field is responsible also for the sediment transport to- and outwards the shoreline. The bottom **shear stress** is dependent on the water depth (i.e. the bathymetry and the actual water level), whilst the suspension rate as well as the bed load movement depend on the particle size distribution (grain size dispersion, typical mean of the distribution lies within range from 0.1 to 0.3 mm). Besides the bottom sediments, the load flow along the shoreline is being fed or diluted by, respectively, the erosion or growth of the coastline. These processes of the coastal dynamics that can reach the values of several hundred metres per half a century are driven mainly by the wave field action on the beach, that has different impact for different water levels and size distributions of the sand particles.

The sinks (sedimentation) and sources (erosion) of the material load transport are dependent mainly on the bathymetry and the configuration of the natural and artificial (hydrotechnical constructions) obstacles, that, interfering with the hydrodynamics, results in the over- or undersaturation of suspended load, and inability or ability to move the bed load. The above opposite conditions produce, respectively, sedimentation and erosion. These processes have reversive influence on the depth redistribution as well as on the grain size dispersion of the bottom material (coarser particles in the erosion zones but smaller ones in the sedimentation regions). The superposition of the human influence on the depth distribution over the natural processes has to be carefully accounted.

The processes of coastal hydrodynamics driving the load transport are :

- water level fluctuations in the synoptic time-scale, due to the action of mainly local winds and the overall atmospheric pressure field; in the cases of the location of the harbour in the river mouth (see Fig. 1) the river run-off (including its possible forcing by hydropower stations' regime) also may affect (enlarge) the water level in the regions of the vertical density stratification;

- wind wave field in the open sea and coastal wave transformation zone;

- longshore currents driven through the transformation of the wave field energy due to (i) non-orthogonality of the wave vector in respect to the coastline (energetic currents) and (ii) non-equal seaward depth profiles in different locations along the shoreline (gradient currents); longshore currents prevail in between the wave-breaking line and the coastline;

- wind-driven currents prevailing seawards from the wave breaking zone.

One have to note also the interrelation of above four elements of the coastal hydrodynamics and their structural dependence on the depth distribution and bottom material. The whole hydrodynamic processes are forced by the local (river run-off, wind velocity and direction) and the global (cyclonic and anticyclonic atmosphere structures, non-homogeneous wind field over the whole Sea or Gulf, etc.) meteorological conditions.

- the fronts of the wind waves transforming in shallow zone reach the wave-breaking line non-parallel to the isobaths;
- energy transformation after breaking the waves produces the long-shore currents with the maximum discharge at the depths of 6 to 7 m along the coast of the Baltic Proper or 3 to 5 m along the coast of the Gulf of Riga;
- the currents carrying the material load incline seawards (to the greater depths) before the wave breakers; here, mainly due to the greater depths, they become oversaturated and the sedimentation occurs;
- the long-shore current becomes even more oversaturated crossing the border of the channel. Due to the fast increase of the depth the bed load transport stops here, whilst the sedimentation of the suspended load depends on the width of the channel;
- passing the seaport, the longshore current is undersaturated; it restores the load transport up to pre-harbour transport capability continuously. This process causes the prolonged erosion of the bottom downwinds from the harbour;
- the decrease of the depths in the upwind side of harbour shifts the wave-breaking zone seawards. The load transport to- and outwards the coastline trends to the growth of the beach (and vice-versa for the downwind region).

Purposes of beach nourishment and expected results (protection vs. recreation)

The main objective for which the submerged nourishment has been performed is the stabilisation of the coast, particularly in recreational beaches where tourist facilities are placed.

Basic principles

To be completed.

Expected benefits

Environmental benefits

Those are related here for benefits on erosion control, modifying the slope of the shoreface and thus acting over the incident wave trains by diminishing their energy (especially in stormy periods).

Social and economical benefits

As mentioned before, the purpose of this method was to protect the beaches along the nourished sector from storm wave attacks, protecting the facilities in the foredune. From the social point of view, the measure provided security for human assets.

Tourism and recreation plays are the principal role in the development of the study area and is very important the conservation of cultural and 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.

In the other hand, 5 thousand inhabitants are potentially threatened latter are particularly vulnerable regarding the flooding during the storm surge events.

Other points importants are the fisheries and aquacultur (Lielupe river mouth provides port facilities for the small-scale fisheries and there is no aquaculture of an industrial scale in the study area), the agriculture and forestry (small-scale gardening colonies while forests mainly serve for recreational and conservation purposes).

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Technical and financial benefits

No information available.

Designing beach nourishment scheme step-by-step

*Collecting baseline information (in reference to **comp 2**)*

No information available.

*Assessing the "do nothing" scenario (in reference to **comp 3**)*

No information available.

Determining adequate sediment characteristics

No information available.

Identifying adequate sediment sources

No information available.

Selecting the adequate nourishment techniques

Some types of Technical measures aplicated had been the foredune and forestry maintenance, Revetment and submerged nourishment.

Establishing environmental mitigation strategies

- *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).

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.

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 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. 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). Source: EUROSION Case Study Gulf of Riga.

Year	Amount in m3
1998	43000
1999	36000
2000	22000
2001	18000

- 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. 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.

Designing long-term monitoring

The continuous wave action on the sandy coasts produces cross-shore sand transport by oscillatory velocities; longshore currents with maximum of velocities and littoral longshore transport close to the wave-breaking line. The restructuring of the cross-shore profiles has time scale between single storm period (wash out of sand bar and/or beach) and season (restoration of bar structure). The direction and magnitudes of longshore currents vary continuously. The analysis of the mean sand transport volumes along the coastline allows specifying overall trends, accumulation and erosion zones, which on a longer time scale has respective impact on the shoreline development. A simple one-dimensional model for the predicting cross-shore distribution of the longshore littoral drift is developed. It accounts for wave generation (fetch model), transformation (incl. breaking), current distribution, formation of suspension, development of bed macroforms, bed and suspended load transport. The application of the model for the chain of cross-shore profiles along Latvian coastline shows that. The prevalence of the southwestern winds is responsible for the significant (typically more than 1 million m3) northward load transport near the Latvian coast of the Baltic Proper. The combination of the fetch with coastline orientation yields, generally, converging southward sand transport (annual values below 100 thousand cubic kilometers) along the coasts of the Gulf of Riga.

The hydrodynamical processes become essentially two or three dimensional in the vicinity of harbours. Typical engineering constructions, which interact with wave fields, water flow patterns and load transport, are wave-breakers, jetties, sediment traps and sea entrance channels of harbours. Two-dimensional model is developed for applications in near-harbour regions (typically up to 10 km zones). It includes two-dimensional, time-dependent description of wave-field, hydrodynamics, bed and suspended load transport, and morphodynamics (bed level changes). The operation of the model in a hind-casting mode allows its calibration and verification.

The operation of the model in forecasting mode allows prediction of the siltation in sediment traps and sea entrance channels during typical and critical seasons; it helps to draw consequences of reconstruction efforts, and is useful for designing of the sediment traps and finding other engineering solutions such as building additional wave-breakers. The applications of described model are found to assist reconstruction of Ventspils and Liepaja harbours.

Factors influencing the success of beach nourishment schemes

Nowadays, the developed harbour industry (the location of 10 seaports of Latvia) disturbs the natural load transport processes by means of constructing the hydrotechnical objects as the wave-breakers and sea entrance channels. The redistribution of the seabed topography, sedimentation in the sea entrance channels, dynamic response (growth or erosion) of the coastline is the cost for the operating seaports. Besides, the sedimentation in the sea entrance channels increases the expenses of the navigation requiring regular dredging works to ensure the safe navigation depths. Thus, the methods for the forecast of the integral sedimentation/erosion volumes, their spatial and temporal distribution, and dynamics of the coastline are necessary. Besides this, the engineer solutions for the optimum wave breaker configuration, overdredge of the sea entrance channels, configuration and depth of the additional (safety) overdredged areas, location of the load material discharge areas are needed to minimize regular dredgeworks, allow their planning, ensure continuous navigation conditions, and reduce the erosion of the coastline.

The most distinct manifestation of the littoral transport occurs in its interaction with hydroengineering constructions of seaports (wave breakers, jetties, and sea entrance channels). Main qualitative features are beach growth in upwind side of harbours while downwind areas suffer from erosion. Siltation in sea entrance channels is a real problem for navigation safety requiring annual allocations to perform dredging works. The optimisation of the measures to ensure safe navigation at minimum costs is especially actually for Liepaja and Ventspils harbours exposed for the Baltic winds and waves.

Assessing and monitoring the environmental and social indicators for beach nourishment schemes

Impact on shoreline stability

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

Impact on natural habitats

Impact on coastal vegetation

No information available.

Impact on coastal fauna

No information available.

Impact on water quality

Impact on water circulation patterns

No information available.

Impact on water turbidity

No information available.

Impact on pollutant concentration

No information available.

Social perception

No information available.

Budgeting beach nourishment schemes

Feasibility costs

No information available.

Environmental mitigation costs

No information available.

Investment and engineering 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 marketrelated 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.

Maintenance and monitoring costs

An exemple of the costs for the mitigation of losses inflicted by the November 2001 storm to the coastal zone of Jurmala municipality are:

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**

Limitations

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 EUROSION Case Study problems of environmental protection - including ecosystems like the Baltic Sea, Gulf of Riga, beaches, dunes and coastal lakes - with potential economic solutions.

References

EUROSION (2004). *Gulf of Riga. Eurosion Case study.* In: Shoreline Management Guide (http://www.eurosion.org)

Web sites:
http://www.paic.lv/en/problemas_2.php

EUCC_Baltic_ICZM_State_of_Art_pdf.htm