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Vulnerability and Adaptation of Polish Coast to Impact of Sea-Level Rise (SLR)

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Abstract

The paper presented contains results of the latest studies on assessment of the vulnerability of the Polish coast to sea-level rise, thus providing the synthesis, development and update of all current works in this field. Apart from a general description of the basic physical and socio-economic coastal characteristics, boundary conditions were defined for further studies on Poland's vulnerability to ASLR. For each of the four areas, into which the Polish coastal zone was divided, a synthesis of threats and vulnerability to the expected SLR was carried out, taking into account characteristic elements and features of the regions.

Basing upon two extreme scenarios of sea-level rise, i.e. ASLR1 with 30 cm/100 yrs (optimistic variant) and ASLR2 with 100 cm/100 yrs (pessimistic variant), the assessment and cost calculation of total protection measures of the endangered areas in the coastal zone related to their capital value to be lost was executed.

Finally, it was found that the protective investments should mainly be undertaken on the west and east coasts, where economically justified. Because of limited funds, it is necessary to concentrate on particularly important and simultaneously strongly threatened regions. The detailed analysis of costs implies that the activities should be undertaken first on the coastal segments adjacent to Gdańsk and Szczecin, where vast agglomerations are located, with concentrated industry and related infrastructure, as well as centres of science and culture.

1. Introduction

The first vulnerability assessment studies of Poland's coastal area to sea-level rise were completed in 1992. This programme, called **VA'92**, was a Dutch-funded sea-level rise programme for Poland's coast. The second comprehensive **VAAP'95** research programme was carried out in 1995 and was one of the coastal component of the US Climate country Study Program – USCSP Poland. The latter programme included feedback from other USCSP components, and created a set of new requirements and boundary conditions, also took into consideration a number of physical and socio–economic developments in Poland in 1992–95.

The **VA'92** programme was based on the seven-step Common Methodology derived by IPCC. The **VAAP'95**, using many segments of Common Methodology re-assessed the changing Polish sea-level trends, included recent data for storm surges and flooding probabilities for the Polish coast and updated a set of prices and socio-economic estimates.

During the last two years, two other comprehensive studies concerning implications of sea-level rise for Poland were carried out. The first one was carried out by the Maritime Institute of Gdansk in 1999–2000 under the project funded by the State Committee for Scientific Research. In general, it concerned assessment of the present vulnerability of the Polish coast to erosive processes and the strategy of protective activities coming decades. The second studies are presently (1999–2001) being carried out under the EU **SURVAS** (*Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies*). The project is coordinated by Middlesex University in the UK and is focused on both local (countries), regional (European) and global (world) problems. Poland is one of the major participants. The main objective of the project is complex analysis, assessment and in turn – basing on the common methodology – unification existing results on coastal vulnerability, on local, regional and global scales. Such a synthesis and unification leads to better assessment and understanding of the threats resulting from climatic changes, including sea-level rise, and is a valuable source of information and data for activities related to *Integrated Coastal Zone Management*. The basic benefits stemming from recent results are:

- elaboration of complex guidelines for synthesis of various local (national) studies on the results of sea-level rise, including respective qualitative requirements;
- application of the elaborated guidelines to synthesis of existing studies carried out in European countries (including Poland), as well as beyond them, in order to assess the European coastal vulnerability to sea-level rise;
- analysis and detailed review of the obtained results in order to improve and unify further studies related to assessment of coastal vulnerability to sea-level rise, carried out on both regional and global scales;
- establishment of a global meta-base of data concerning the above problems and the studies carried out up until the present moment on various time-spatial scales, as well as other investigative results available – inter alia – via Internet.

2. Polish Coast

The Polish open sea sandy coast is about 450 km long and stretches along the south Baltic coast, Fig. 1. Almost all Poland's territory (more than 99%) lies in the catchment area of the Baltic Sea, where about 54% belongs to the Vistula

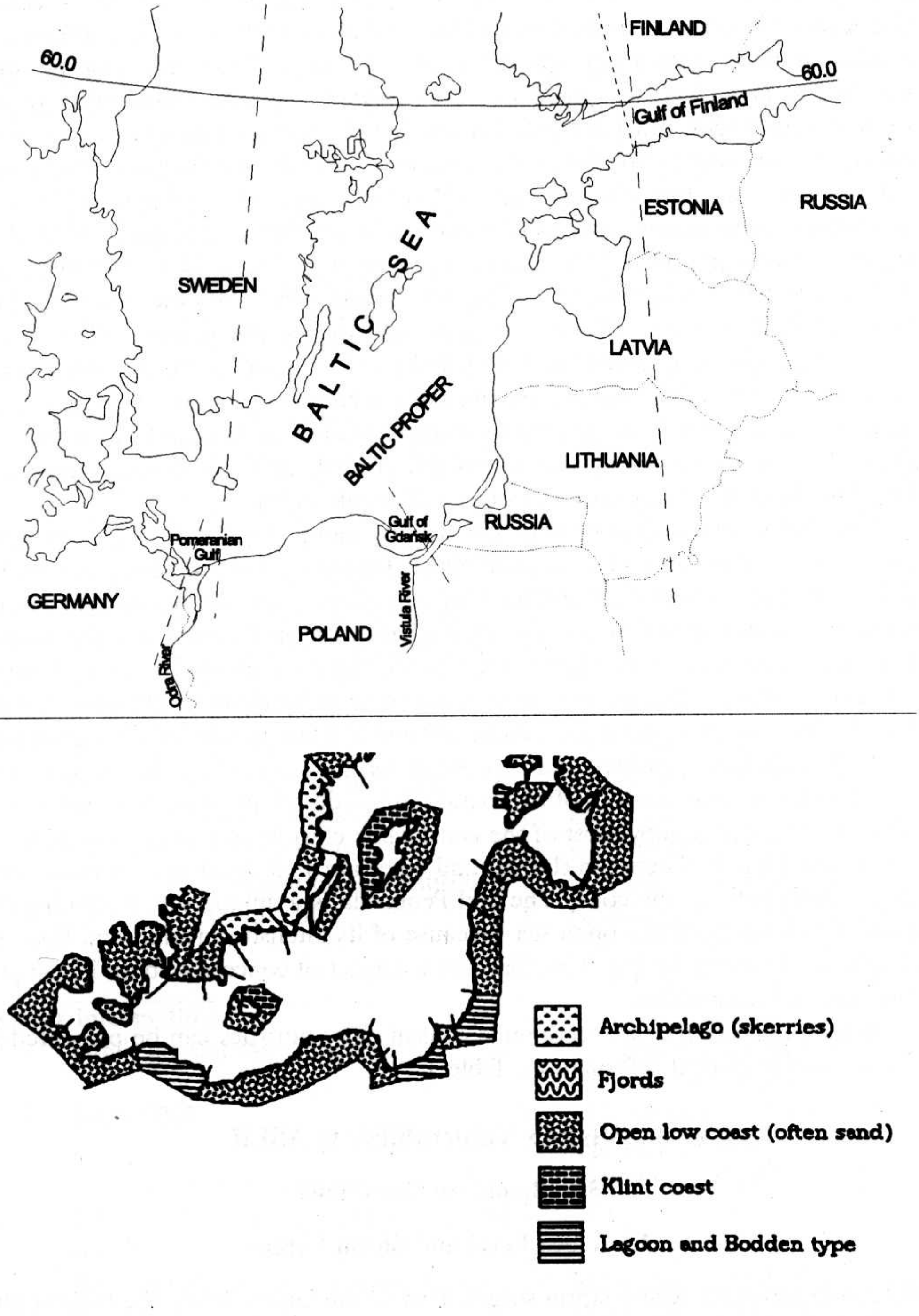

Fig. 1. Location of study area and type of coast

drainage system, 34% to the Odra and 11% goes to the direct basin of the Baltic. During the last century, more than half of Poland's open sea coast was affected by erosion problems with a rate approximately −0.5 m/yr. The cliffs along the open sea eroded at an average speed of −0.34 m/yr. Long term observation of the shoreline (dune/cliff foot) changes showed that the average rate of coastal retreat during the 100-year period was −0.12 m/year, during the period 1960–1983 it was −0.5 m/year, and during the period 1971–1983 it reached −0.9 m/year. Erosion extended over increasing lengths of coastline: in the 100-year period – 61%, during the 24-year period – 72%, and in the 13-year period – 74%. The dune/cliff foot was less intensely eroded. During the period 1960–1983 the dune/cliff foot line retreated at a rate of −0.16 m/year, and during the period 1971–1983 at −0.3 m/year (Zawadzka-Kahlau 1999). Evident in Poland, with increasing tendency, erosive shoreline changes are presently a common feature of many coastal segments in the world. As proved by numerous observations and investigations, about 70% of global (sandy) shorelines are eroded, 20% is relatively stable and 10% is subject to accumulative processes (Pruszak 1991).

The Baltic sea is shallow with low salinity along the Polish sandy coastline amounting to 0.6–0.8% (1% at maximum). Poland's coastline forms two major gulfs – the Pomeranian Gulf and the Gulf of Gdańsk, and two lagoon-type bodies connected with the sea by narrow straits: the Szczecin Lagoon and the Vistula Lagoon. Subsidence is negligible, only locally up to 1 mm/yr. Thus two major estuarine systems occur on the Polish coast – the Odra River in the west and the Vistula River in the eastern part, about 700 and 850 km^2 in size. A substantial part of the Vistula Delta, Żuławy, is a depression reaching almost 2 m below sea-level.

The Polish coast consists of two basic types – dunes and barrier beaches, and cliffs. The former occupy most of the coast while cliffs stretch along less than 100 km. Coastal barriers between the sea and lakes are well developed in the central and eastern parts of the coast. The Hel Peninsula is a unique spit separating the Gulf of Gdańsk from the open sea. Because of its intensive erosion and flooding during severe storm surges, it has become a subject of concern to both Polish and international authorities.

Basic physical and socio-economic coastal characteristics can be presented in the form of statistical information, Table 1.

3. Poland's Vulnerability to ASLR

3.1. Boundary Conditions

3.1.1. Sea Level and Storm Surges

Poland experiences severe storm surges. Due to the largest fetch, the highest and most dangerous waves and storm surges are generated by north and north-east winds. Winds from the western sector can also cause large storm surges, especially

Table 1. Basic physical and socio-economical data

COASTAL CHARACTERISTICS	STATISTICAL DATA
Main Coastline data:	
– Total length of the coastline	843 km
– Total land area	312.685 km^2
– Length of open coastline, i.e. exposed to waves	430 km
– Length of sheltered coastline, i.e. estuaries, lagoons, enclosed bays, etc.	413 km
– Length of sandy beaches	358 km
– Coastal UNESCO sites	1 (Słowiński National Park)
Coastline protection measures:	
– Total length of protected coastline (including lagoon dykes)	316 km
– Length of hard protected coastline (including seawalls – 62.8 km, groins – 98 km, others – 2.4 km)	155 km
– Length of soft protected coastline	56 km
– Length of coastline with harbour structures	14 km
Selected socio-economic data:	
– Total national population	38,666,983 (1998)
– National population growth rate	0.05% (1998), 0.02 % (1999)
– Total coastal zone population	ca 1.5 mln
– Coastal zone growth rate	4.2% (1999)
– Name and population of nationally important coastal cities	Gdańsk (458,988), Gdynia (253,521), Kołobrzeg (47,500), Szczecin (416,988), Świnoujście, Ustka (17,200)
Other information:	
– Other coastal infrastructures	Shipyards: Gdańsk, Gdynia, Szczecin-Świnoujście
– Total GNP	152,500 millions US$ or 617 mld PLZ (1999)
– Value capital at national averages	12,000 billion US$
– Total population life expectancy (in years)	74.5
– Total population below poverty line	Rural area – 21.2 (%) Urban area – 9.3 (%) (1996)

where the storm is coupled with the intrusion of water from the North Sea into the Baltic. Such situations occur when the wind blows from the west for a long time and there is a distinct difference of atmospheric pressure between the North Sea and the Baltic. Surges greater than 70 cm above the mean sea-level (MSL) referred to Amsterdam (MSL-500 cm) have a probability of less than 0.75 in any given year. The 100-year design water level can be approximated as 650 cm (i.e. 150 cm above MSL), while its counterpart for the return period of 1000 years is about 680 cm (i.e. 180 cm) (Rotnicki & Borówka 1990). Long term annual sea-level rise is presented in Table 2.

Table 2. Sea level rise for selected Polish stations in the years 1951–1985 (Dziadziuszko, Jednorał 1988)

Station	Growth rate [mm/yr]
Świnoujście (western border)	1.4
Ustka	2.0
Hel	1.7
Gdańsk	2.9
Tolkmicko (eastern border)	1.5

The long-term sea-level changes at three Polish stations registered in 1883–1985, after Dziadziuszko & Jednorał (1988) are shown in Fig. 2. These records show that for the last century the mean rate of sea-level rise is approximately about 20 cm/100 years. Due to present trends of emission of the greenhouse gases, mainly carbon dioxide and the resulting climatic changes (temperature increase), the approximate assessment of the sea-level rise for the year 2100 indicates the value between 30 (optimistic variant) and 100 cm/100 years (pessimistic variant). The last value seems to be an over-estimated quantity though. Various latest assessments and reports show that the 100-year accelerated sea level rise (ASLR) can be between 30 cm and 100 cm, and indicate that 50–60 cm is the most probable range.

3.1.2. Boundary Contours and Impact Zone

Two main sea-level rise scenarios of 30 cm (ASLR1) and 100 cm (ASLR2) by the year 2100 have been assumed as boundary conditions for the entire Polish coast. Three "impact zones" have been selected for Poland's climate-change coastal studies. The selection of the impact zones has been based on the extent of the sea-level rise assumed +0.3 and +1.0 m plus possible flooding due to storm surges (1.5 m), which gives the maximum inland boundary of +2.5 m above MSL. So, the land up to +2.5 m isohypse has been assumed as being vulnerable to the impact of 1 m ASLR plus storm surges with a return period of 100 years, Fig. 3.

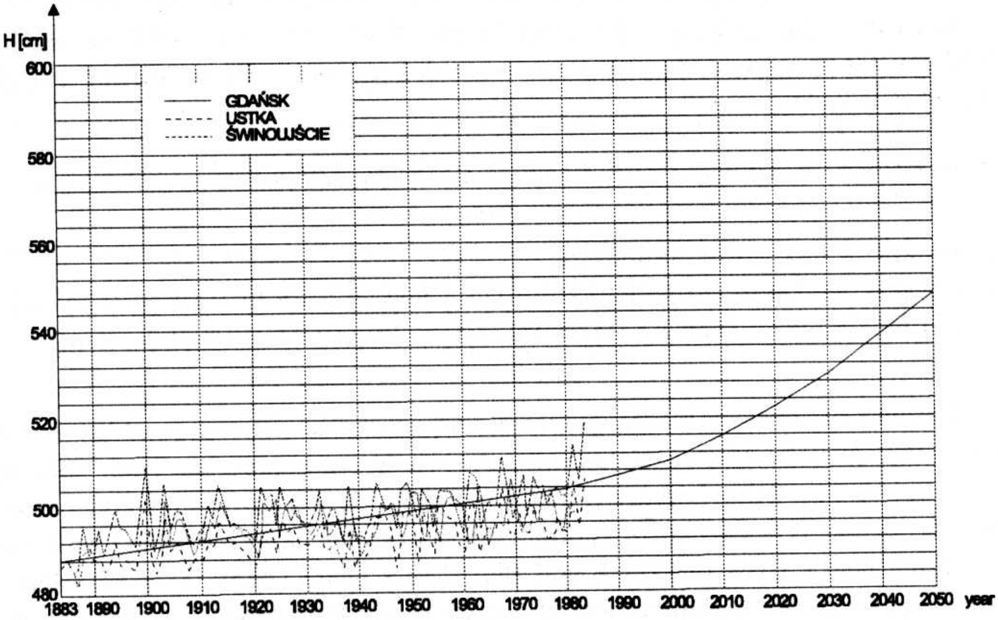

Fig. 2. Long term sea-level rise – past records and future prediction

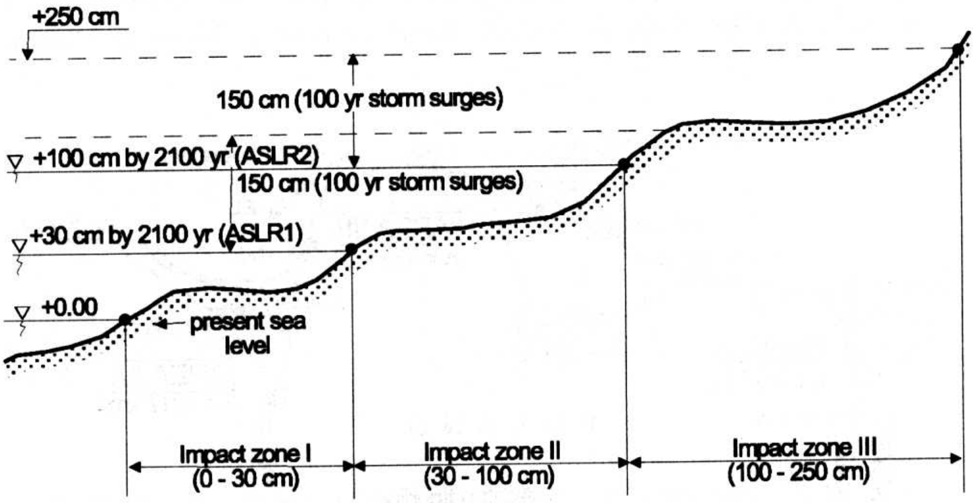

Fig. 3. Definition of boundary contours and impact zones for Poland's climatic change coastal studies

Assuming hydrological conditions and existing coastal land topography three impact zones have been defined. Inundated (flooded) or lost areas have been deduced as impact zone I at ASLR1 (30 cm/100 yrs) and zones I+II at ASLR2 (100 cm/100 yrs), while the risk zones were defined as II+III at ASLR1 and III at ASLR2, Table 3.

Table 3. Inundation and risk in terms of impact zones for Poland's climatic change coastal study area

Scenario	Area inundated	Area at risk
ASLR1	Impact zone I (0–0.3 m)	Impact zone II + III (0.3–2.5 m)
ASLR2	Impact zone I + II (0–1.0 m)	Impact zone III (1.0–2.5 m)

Because of considerable geographical and economic differences of the Polish coast and diversity of coastal features, the whole study area has been split up into four Areas. Odra Estuary (Area I – 595 km^2), western dunes and barrier beaches (Area II – 244 km^2), central-east dunes and barrier beaches with Hel Peninsula (Area III – 173 km^2), and the Vistula Delta (Area IV – 1217 km^2). Area I includes the agglomeration of Szczecin (and Świnoujście), while Area IV encompasses Gdańsk, Gdynia and Sopot, together with Elbląg, Fig. 4. Areas II and III are similar to each other as they comprise only open sea coast without large river systems, have lower concentrations of industry with rather low land value and are also not densely populated. In general, the specified areas reflecting the major geographical differences along the Polish coast, also coincide with the administrative division of the coast under the jurisdiction of Maritime Offices.

Fig. 4. Polish coast – study areas and flood risk zones

The impact zones between contour lines 0–0.3 m, 0–1.0 m and 1–2.5 m cover areas of 86,510 ha, 178,905 ha and 48,715 ha, respectively. In total this affords about 2300 km^2, plus about 50 km^2 of beach and dunes that are likely to disappear as a result of ASLR2 and about 20 km^2 due to ASLR1, Table 4, after Zeidler (1992) with recent modification. The impact zones I and (I+II), e.g. only within Area I measure in all about 163 and 490 km^2, respectively. The most substantial share of the surface area at stake is agricultural land. Of the total 2350 km^2 in the three impact zones, 1750 km^2 (the agriculture land) are situated in Area IV, i.e., the Vistula Delta, with its fertile alluvial depressions. Generally, about 65% vulnerable agriculture land is situated within Area IV, as against 23% in Area I and 12% in both other areas (Area II and III).

Table 4. Distribution of Land-Use Categories in Impact Zones I, II and III; area in hectares

Area	Highly productive agriculture	Low productivity agriculture	Land suitable for pasture and agriculture	Forest	Rural	Urban	Industry and infrastructure	Recreation	Nature	Total
Impact Zone I – (0.0–0.3 m)										
I	90	12,455	2.935	1,415	30	40	96			Surface
II		30	400						430	Area =
III		130	40							86,510
IV	65,870	1305	1,855		352	130	886			ha
Total	65,960	12,745	5,260	1,415	382	170	982		430	
Impact Zone I + II – (0.0–1.0 m)										
I	297	35,338	5,735	7,790	650	640	771	35		Surface
II		11,605	995	2,745	110	90	74		485	Area =
III		11,531	118	24	17	5	31	12		178,905
IV	89,910	1,930	2,565	1,460	2,790	705	1,604	95	285	ha
Total	90,207	60,404	9,413	12,019	3,567	1,440	2,478	142	770	
Impact Zone III – (1.0–2.5 m)										
I		7,985	145	1,890			402			Surface
II		5,585		2,515	370		52			Area =
III		3,260		330	155	85	56	730		48,715
IV	21,920	200		795	1,215	815	596			ha
Total	21,920	17,030	145	5,530	1,740	900	1,106	730		

The number of people vulnerable in case of sea-level rise, is highest in Area IV, Table 5. About 38% of the total population in the study area is prone to temporary (not more often than once per year) flooding in Area IV (Zeidler 1997).

Table 5. Population of the study area

Area	Impact zone	Urban	Rural	Total
I	I (0–0.3 m)	1,630	3,450	5,080
	II (0.3–1.0 m)	21,080	9,630	30,710
	III (1–2.5 m)	28,960	2,940	31,900
II	I	0	270	270
	II	1,210	4,580	5,790
	III	870	2,880	3,750
III	I	0	110	110
	II	740	9,310	10,050
	III	1,550	2,490	4.040
IV	I	9,590	25,810	35,400
	II	40,980	17,650	58,630
	III	36,080	13,030	49,110
Total		142,690	92,150	234,840

3.2. Flood Areas

3.2.1. Area I (Odra Estuary)

Most of Area I constitutes agriculture land and is linked with the Odra Estuary. Impact zones I and (I+II) and III within Area I measure a total of about 163, 490 and 100 km^2, respectively. In impact zone I most of the people threatened by permanent or temporary flooding live in rural region (twice as much as for urban areas). This stems from the fact that the sea-level rise corresponding to impact zone I will affect low lying land (mainly agriculture) adjacent to Szczecin Lagoon and the Odra river mouth. The situation is different for impact zones II and III, where upper areas embracing towns and cities are threatened, thus posing a threat to a predominantly urban population. For impact zone II the ratio of urban to rural population exposed to the threat is 2:1, whereas for impact zone III it leaps to 10:1.

Full protection of the Odra estuary (Area I) means preservation of the polders on the estuary peripheries. All existing polders and dykes must be adapted to the new situation, and many new dykes must be constructed. In all, 107 and 280 km of new dykes must be constructed in Area I under ASLR1 and ASLR2, respectively. The lengths of adapted dykes are 243 and 324 km. The outline of full protection against ASLR1 and ASLR2 for the most important part of Area I, i.e. Polish part of the Odra estuary, is shown in Fig. 5. The dyke crest at present is 1.5–2 m above MWL of the Szczecin Lagoon, and this freeboard should be retained in the future. Wharves in ports and urban areas must be raised. The cost of full protection in Area I is estimated between 0.5 billion US $ (ASLR 1) and 2 billion US $ (ASLR 2), i.e. less than 10% of the value (15 billion US $) of the lost property and land.

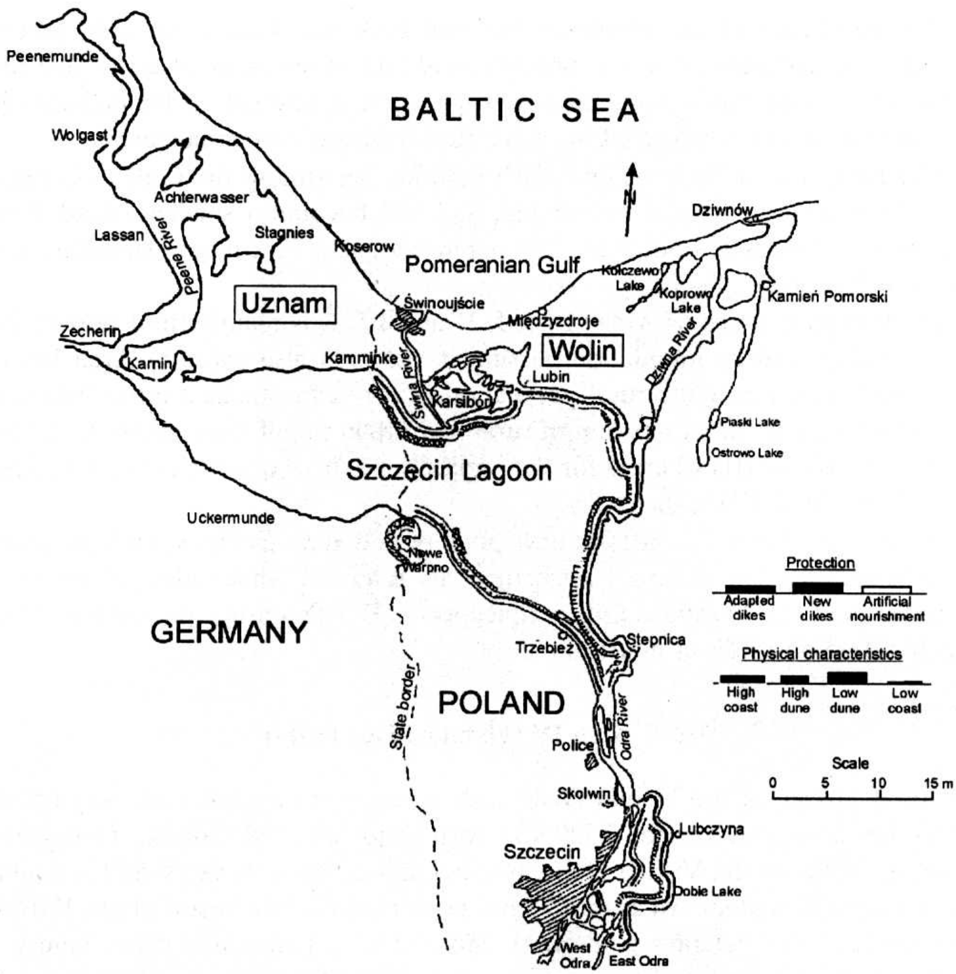

Fig. 5. Physical characteristics and full protection for the Odra estuary (Polish part), after Zeidler et al. (1992)

3.2.2. Area II and Area III (Central – Open Coast – Part of Study Area)

In Areas II and III, a chain of coastal barrier lakes exists. Narrow coastal barriers between the sea and low-lying lakes (many lagoons or embayment areas) could erode, making the hinterland easily accessible to seawater. The higher level attained during storm surges in ASLR scenarios will destroy foredunes and erode barrier islands and spits. The lowered barriers will then be susceptible to storm washover. The lakes will grow more saline.

The main part of the Słowiński National Park and Łeba dune field (about 130 km^2 – encompassing water, swamps sand and other areas of ecological importance), a memorable national landscape, special enough to be included in UNESCO's list of the world's Biosphere Reserves, are also endangered.

Hel Peninsula, a fairly unique spit formation separating the Gulf of Gdańsk from the open sea, is most vulnerable, and will become a smaller island if no protective measures are adopted. The peninsula has a 72 km long shoreline and is narrow less than 200–300 m.

In all impact zones of Area II i.e. I, II and III, it is mainly rural population that is endangered by inundation. A similar situation also exists in Area III. In the impact zone I only the rural population is at risk in practical terms, whereas for impact zone II the proportion of rural and urban population equals 4:1 (Area II) and 11:1 (Area III) whereas for the impact zone these quantities are 3:1 (Area II) and 2:1 (Area III) respectively.

To protect Areas II and III, new polders and new facilities such as pump stations, drainage and other infrastructures are required, while older polders must be redesigned. In Maritime Office concepts of Hel Peninsula protection it has largely relied on artificial nourishment.

3.2.3. Area IV (Vistula River Delta)

The total surface of the Vistula Delta with an average population density of 145 inh/sq. km covers an area of 2,320 km^2 with major cities of Gdańsk, Elbląg and Malbork. Much of the Vistula Delta area belongs to study Area IV and is mainly the agricultural land known as the Żuławy polder district and covers about 180,000 hectares (0.6% of Poland's land area). Most of its depression and low land will be damaged under all ASLR scenarios. The dikes already built will be too low for the new hydrological conditions, especially ASLR2. The 180,000 ha are more than 65% of all the agricultural vulnerable area.

Gdańsk industry (ports included) occupies 430 and 330 hectares in impact zones I + II and III, respectively. The endangered urban areas of Gdańsk cover 450 and 680 ha in the same zones. Full prevention measures should be taken to avoid any loss of this valuable and historical piece of our study area.

Area IV is the most vulnerable as compared with others. The population to be relocated due to sea-level rise (impact zones (I + II) is the highest (above 21% of the grand total). The number of people suffering from temporary flooding (not more than once per year) is almost 38% of the entire population of the study area (VA'92). The area losses under ASLR1 ASLR2 are very heavy – 672 km^2 (80% of all Area I–IV) and 948 km^2 (55%) respectively. Graphic illustration of land loss in Vistula River delta caused by lack of protection from rise in sea-level of 0.3 m (ASLR1) and 1.0 m (ASLR2) is presented in Fig. 6.

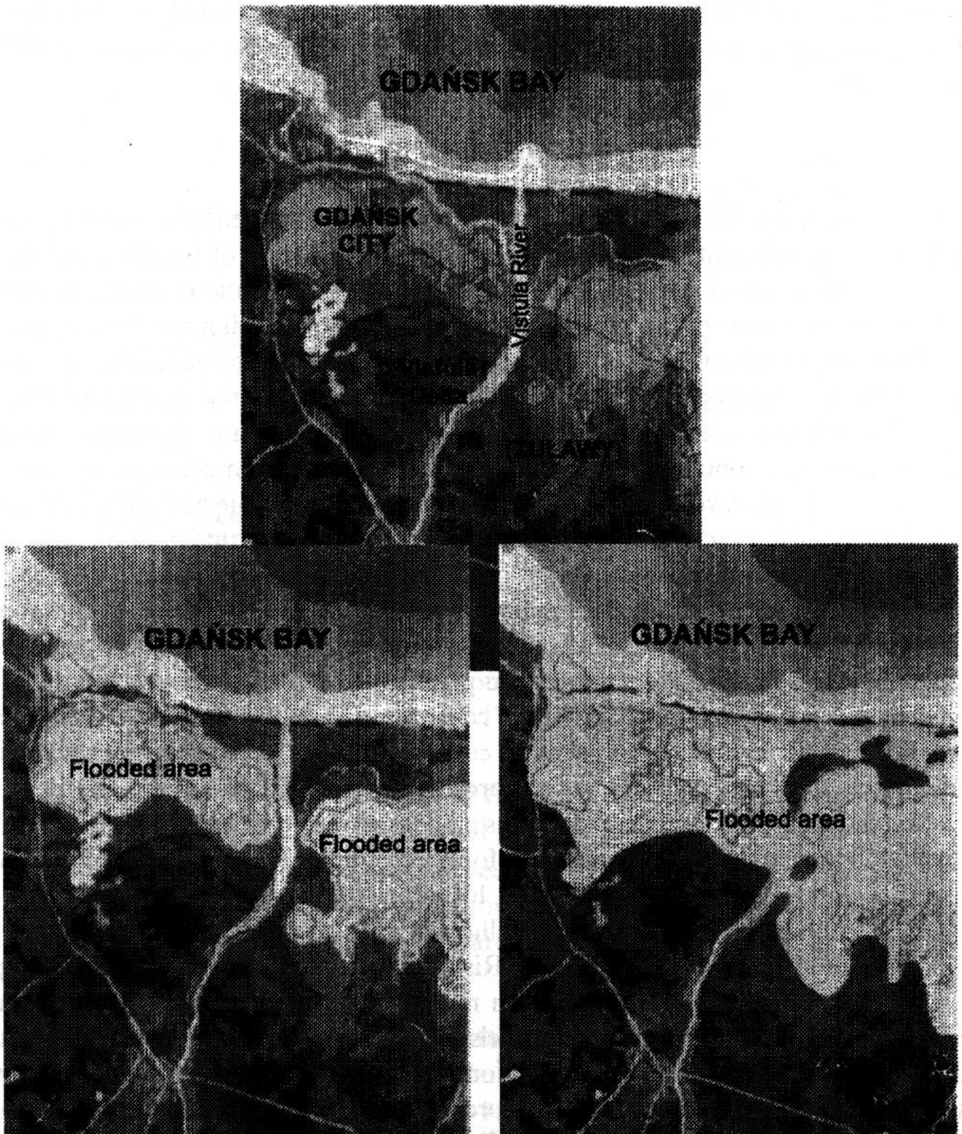

Fig. 6. Vulnerability of Area IV to flooding for two variants of ASLR with no measure adopted scenario

Full protection of Żuławy polders at ASLR2 requires the bulk adaptation of existing dykes and construction of some new dykes and storm and flood prevention facilities. At ASLR2, 52 km of new dykes should be constructed and 647 km of those presently in use adopted. Under ASLR1, the respective numbers are 13 km and 600 km.

4. Discussion and Summary

The existing scenarios of increase of greenhouse gases concentration in the atmosphere, being different in details and assessment of the rate of increase, definitely indicate that mean rise in sea-level, accompanying to climatic changes, is inevitable during the next tens of years (Pruszak 1991). The resulting problem is how to minimize the undesirable effects of this process and how to resist it. This concerns both technical aspects and those, related also to the immaterial domain of human life. The determination of the starting moment for the firm protective actions and their range is one of the most difficult aspects of human activities against effects of rise in sea-level. Because such activities will be connected with high costs and because the exact rate of increase in sea-level is still under discussion, the philosophy of attentive observations of climatic changes and related increase in sea level is presently initiated in many countries. Various scenarios of the above changes are being prepared and updated continually, their effects are predicted together with selective shore protection planning and further development of the process is awaited. Poland is one of the countries that follow the above way. There are, however, a few countries trying to consider the sea-level increase in advance, adequately designing important structures in regions adjacent to the shore.

As shown by various investigations and analyses, e.g. Zeidler (1997), more than 2300 km^2 and 235000 people are found vulnerable to the impact of sea-level rise in Poland. The total cost of land loss due to ASLR2 has been assessed at nearly 30 billion US$ plus some 18 billion in case of flooding, while the cost of full protection reaches US$ 6 billion. Rising prices urge prompt protective steps.

As coastal processes, together with rise in sea-level, are large-scale phenomena, the decisions and technical enterprises must concern vast areas, often greater than those designed for direct protection. Therefore, socially accepted high costs are necessary. This requires a complex, reasonable approach, accounting for many users of a coastal zone within the so-called Integrated Coastal Zone Management (ICZM). Hence, all technical-economical-social activities aimed at pejorative effects of sea-level rise, before final decisions, should base on the optimisation of profits and losses or on feasibility studies, comprising protect-or-perish analyses.

Assuming the division of the Polish coast into four basic regions, two main adaptation strategies have been compared and with more details in physical and socio-economic terms analysed and assessed. The first one was the retreat (R) – do nothing strategy while the second one was the full protection (FP) adaptation strategy. The last one was defined as the implementation of all feasible protection measures to avoid loss of any coastal land or value. Some results of the vulnerability analysis for these two major strategies and assumed areas, Fig. 4, are shown in Table 6 and Figures 7A, B, C.

Table 6. Poland's coastal vulnerability to ASLR1 and ASLR2 (prices 1995 year)

Impact category	Unit	ASLR1		ASLR2	
		Retreat (R)	FP	Retreat (R)	FP
Capital value lost	10^9 US $	6	–	28	–
People relocated	10^3	8.5	< 0.1	146.1	0.1
People at risk	10^3	31.7	< 1	50.3	< 5.8
Capital value at risk	10^9 US $	40	< 5	18	< 5
Damage (salinity)	10^9 US $	< 0.01	< 0.01	< 0.01	< 0.01
Ecolog. area lost	km^2	1.2	–	3.4	1
Special area lost	km^2	2.7	1	7.9	3
FP implement. cost	10^3	–	2.3	–	6.1
Annual maintenance	10^3	–	0.01	–	0.03

On the basis of the estimations of the protection cost with respect to the capital value lost, it was found that, inter alia:

- in the case of ASLR1, the full protection cost (FP) is substantially lower than the value at loss (Area I and IV), comparable for Area II and much higher for Area III;
- in the case of ASLR2, the ratio of the full protection cost to capital value at loss is low (less than 35%) for all four Areas.
- in Area III, the land is important because of landscape features and ecological aspects, e.g. in Słowiński National Park or Łeba dune field. The protection costs are, however, incomparably higher than the measurable value of the land.

Thus, protective investments should mainly be undertaken on the west and east coast, where economically justified. Due to limited funds, it is necessary to concentrate on particularly important and simultaneously strongly threatened regions. The detailed analysis of costs implies that the activities should be undertaken first on the coastal segments adjacent to Gdańsk and Szczecin, where vast agglomerations are located, with concentrated industry and related infrastructure, as well as scientific and cultural centres.

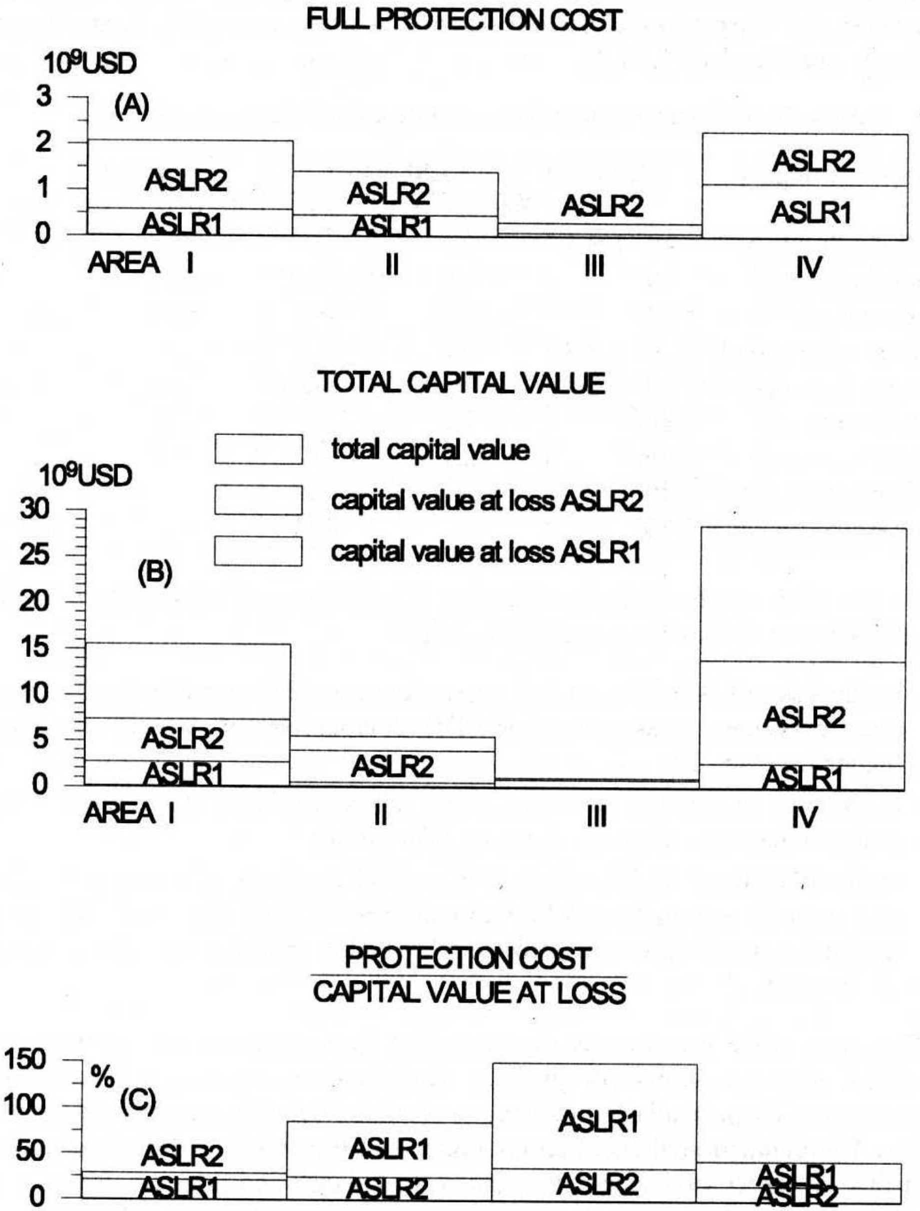

Fig. 7. Assessment of full protection cost, total capital value and ratio of protection cost to capital value at loss for assumed areas

References

Dziadziuszko Z., Jednorał T. (1988), Sea level oscillations the Polish coast (in Polish), *Studia i Materiały Oceanologiczne*, 52, 215–238.

Pruszak Z. (1991), Rise of Mean Sea Level and shore protection problems (in Polish), *Inżynieria Morska i Geotechnika*, No. 1, 17–18.

Pruszak Z. (2000), *Existing national problems and coastal management arrangements*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–7.

Pruszak Z. (2000), *Appraisal of National/Subnational Vulnerability Assessments – Poland*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–10.

Pruszak Z. (2000), *Climate (environmental) change and Socio-Economic-Scenario. SURVAS Matrix – Sheet 1 (ASLR1)*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–7.

Pruszak Z. (2000), *Climate (environmental) change and Socio-Economic-Scenario. SURVAS Matrix – Sheet 2 (ASLR2)*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–5.

Pruszak Z. (2000), *National statistic and trends with an emphasis on the coastal zone. SURVAS Aggregation region: Europe-Poland*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–3.

Pruszak Z. (2000), *SURVAS Products and Potential End Users – Poland*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–5.

Pruszak Z. (2000), *Qualitative data and Appraisal – Poland*, SURVAS Country Report, IBW PAN-Gdańsk – Middlesex University-Enfield, 1–7.

Pruszak Z. (2000), *Implication of ASLR for Poland*, Proc. of SURVAS Expert Workshop on "European Vulnerability and Adaptation to Impact of Sea-Level Rise", Hamburg, 19–21 June 2000, 95–99.

Rotnicki K., Borówka R. (1990), *Impact and a future sea-level in the Polish Baltic Coastal Zone*, In: J. G. Titus (Ed.), *Changing Climate and the Coast*, Vol. II, Washington, 49–65.

Rotnicki K., Borówka R., Devine N. (1995), Accelerated sea-level rise as a threat to Polish Coastal zone-quantification of risk, from "Polish Coast Past, Present and Future", *Journal of Coastal Research*, Special Issue, No. 22, 111–134.

Zawadzka–Kahlau E. (1999), *Developmental Tendencies of the Polish South Baltic Coast* (in Polish), GTN, Gdańsk, 1999, pp. 147.

Zeidler R. B. (editor) (1992), *Assessment of the Vulnerability of Poland's Coastal Areas to Sea Level Rise*, H. T. S. Gdańsk, pp. 165.

Zeidler R. B. (1997), Climate Change Vulnerability and Response Strategies for the Coastal Zone of Poland, *Climate change*, 36, 151–173.