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♦

COASTAL ENGINEERING

Monography

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Foreword

Coastal engineers are often interdisciplinary involved in integrated coastal zone management, also because of their specific knowledge of the hydro- and morpho- dynamics of the coastal system. This may include providing input and technology for e.g. environmental impact assessment, port development, strategies for coastal defense, land reclamation, offshore wind farms and other energy-production facilities, etc. Engineers will need to design coastal and offshore structures with climate change adaptation in mind. Addressing this challenge requires a greater analysis of the vulnerabilities of existing coastal and offshore structures, including a consideration of potential drivers and the circumstances contributing to more frequent structural failures and the loss of system functionalities and developing robust climate risk management strategies for building and improving the resilience of assets.
Climate change generates impacts on the environment, particularly in vulnerable systems like coasts, which are exposed to sea level rise. Moreover, potential changes in wind and atmospheric pressure patterns will modify hydrodynamic processes like storm surge and wave climate, which are fundamental driving terms on the coast.

In this context, the authors present in this book several aspects related to coastal engineering and the influence of climate change in this field, such as: *Coastal areas, Exposure and sensitivity in areas of coastlines, Adaptive strategies and capacity in the context of coastal areas, Case study: the factors and the constraints affecting adaptive capacity, General elements regarding the wave phenomenon, Theoretical treatment of the wave phenomenon, Environmental coastal engineering applications (softwares applications), ArcGis-Introduction and applications in coastal engineering.*

Authors

CONTENT

Chapter 1

COASTAL AREAS

1.1. Definition and importance

"The world's coastal areas represent only 20% of the available land but host between 40% and more than half of the global population (Burke *et al.* 2001) [1]. No single definition can encompass the complexity of coasts, and the demarcation of coastal boundaries is no easy matter, for coastal areas are complex systems composed by a range of terrestrial, intertidal, and marine environments with seaward and landward zones of influence that stretch far inland and out to sea.

Different countries use different definitions and boundaries for coastal zones variably based on a combination of ecological, geographical, socioeconomic, historical, political, administrative, and legislative reasons [2]. While certainly informed by the ecological and geophysical characteristics of the coasts, these definitions are very much determined by functional and management requirements.

Coastal areas have been centers of human activity throughout history and current trends indicate that migration toward these zones is continuing. The main reason for this is that the rich variety of ecosystems and habitats in coastal zones provides a range of goods and services critical to human sustenance and well-being, particularly food production (e.g. fisheries and aquaculture), raw materials, and transportation options.

Coastal areas provide also other ecological and socioeconomic services with deep interrelations between them: erosion control of land and intertidal ecosystems (e.g. wetlands and salt marshes), storm protection, water purification, nutrient recycling, and recreation (tourism).

Due to their unique location, coastal areas are also at the receiving end of impacts coming both from the sea and from the land. This exposes coastal areas to the influences of climate change either directly (sea-level-rise, storm surges, floods, droughts) or indirectly through events that originate off-site but whose consequences propagate down to the coasts (river floods and changes in seasonality, pulses, quality of run-off)"(Figure 1.1))[2].

Figure 1.1 Map of ECA region[2].

1.2. Importance of coastal areas in ECA.
1.2.1 Social dimension of coastal areas

"Coastal areas are most often defined through a combination of physical-geographical and management criteria. However, this presents difficulties when trying to assess the socioeconomic or biodiversity conservation value of coastal areas through the use of global data. To overcome this limitation, coastal areas are commonly defined as:

"intertidal and subtidal areas on and above the continental shelf […] areas routinely inundated by saltwater, and adjacent land, within 100 km from the shoreline" (Martinez *et al.* 2007).[13]
Using this definition, the social importance of the coastal areas in ECA basins is demonstrated by the percentage of population living within 100 kilometers of the coast
(Figure 1.2 and Table 1.1). Albania and Estonia are small countries, which is why almost the entirety of their populations is included in this group.

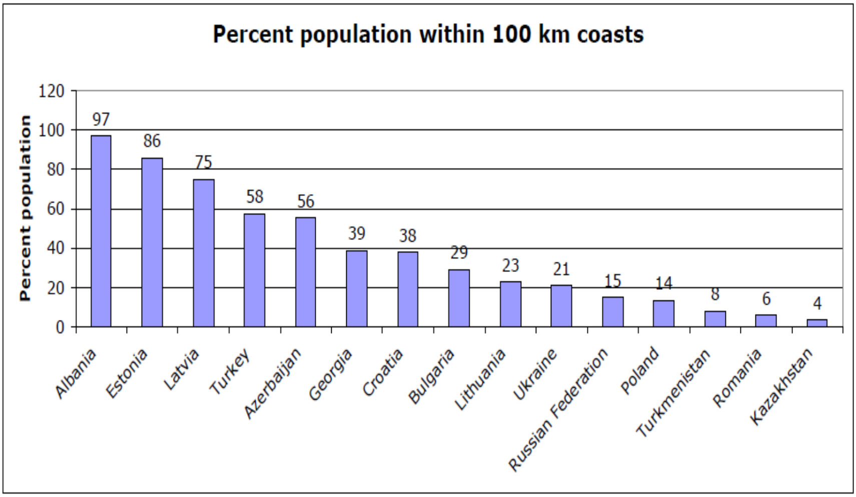


Figure 1.2 Percent of population living within 100 km from the coast. Twelve countries out of 15 have more than 10% of the total population located within 100 km of the coastline.[1]

Table 1.1 Percentage of total population living within 100 km of coastline – average per basin

Sea[1]	Adriatic Sea[2]	Baltic Sea[3]	Black sea[4]	Caspian sea[5]
Average population	68%	49%	28%	21%

1 sea
2 Includes Croatia and Albania
3 Includes Estonia, Latvia, Lithuania, Poland
4 Includes Bulgaria, Romania, Georgia, Ukraine, Russian Federation, Turkey
5 Includes Azerbaijan, Turkmenistan, Kazakhstan, Russian Federation

1.3. Climate change in coastal areas

Climate change causes various impacts on ECA coastal areas through extreme weather events, long-term changing averages in climatic variables and increased weather variability (Table 4). Sudden severe phenomena such as storm surges, and gradual changes like SLR, will directly affect human well-being by damaging investments and infrastructures, and indirectly through modification of coastal ecosystems and habitats (Alcamo *et al.* 2007). Although climate change may offer positive opportunities as well as cause harm, it is expected that the latter will far outweigh the former. Furthermore, the IPCC reports that for the first decades of the 21st century some of these events will be heavily influenced by the North Atlantic Oscillation (NAO)4.

According to several models these impacts would become most significant after 2050 (Alcamo *et al.* 2007). However, two aspects must be considered: (1) several observations indicate that climate change may be more dramatic than predicted (see glacier melt section), (2) coastal exposure to climate change can vary greatly according to interactions between global, regional, and local weather and biogeophysical factors. The rate of sealevel- rise is influenced by cyclical regional weather patterns, local atmospheric pressure, sea thermal expansion, coast subsidence, uplift caused by tectonic movements, and other hydrogeological factors (Nicholls *et al.* 2007; Nicholls and Klein). While the IPCC projects Special Report Emission Scenarios (SRES) indicatinh a global SLR of between 0.09 to 0.88 meters by 2100, in Europe the interaction with local factors may induce a SLR that could be 50% greater than the global estimates (Alcamo *et al.* 2007).

Given the uncertainty of current estimates, it is critical that an adaptation strategy be put into action in ECA. Adaptation to climate change in the context of coastal areas is defined as a policy process entailing decisions on policy and technological interventions that aim at reducing the vulnerability of the system to climatic changes. This section follows the general approach of the Umbrella Report in defining vulnerability as a function of exposure to climate change, sensitivity of the system, and adaptive capacity (Figure 1.3).

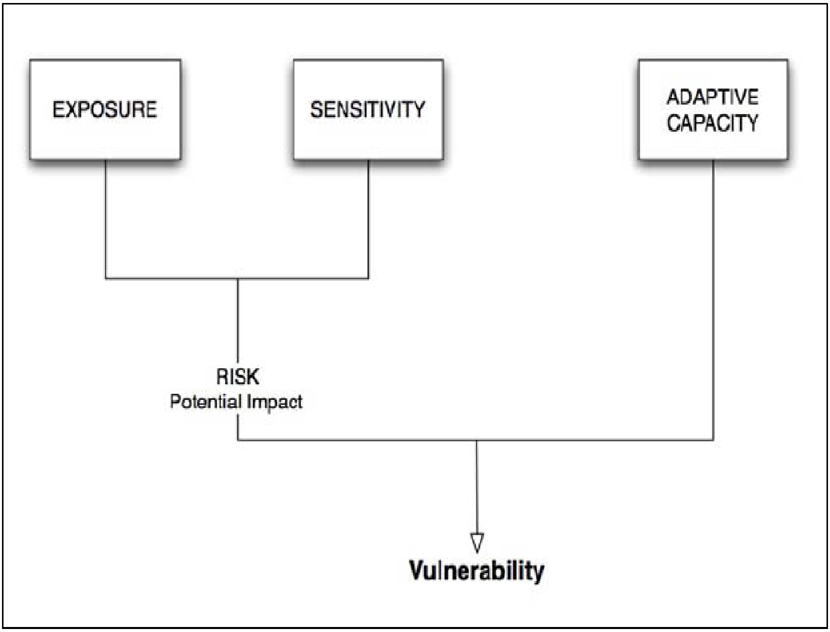


Figure 1.3 Vulnerability as a function of exposure, sensitivity, and adaptive capacity.

Sources: Nicholls *et al.* 2007; Allen Consulting Group 2005.

In order to reduce the vulnerability of coastal areas to climate change it is therefore necessary to examine the exposure to climate change of the basins of interest, their sensitivity to the changes, the adaptive capacity and other factors that may influence these components. Some adaptation options can then be proposed to reduce vulnerability by reducing sensitivity to climate change and by promoting the development of adaptive capacity (Table 1.2).

Table 1.2. Climate change events

Projections	**Change 1**	**Change 2**	**Effects on coastal resources**
Increase in mean annual temperature	• Less ice-cover on the sea • Thermal expansion • Less	• Reduction of ice cover on the sea implies the wind will producer larger waves and there will be a higher incidence and	

Increase in mean sea surface temperature	convection mixing • Increased storm intensity in tropical and temperate waters • Temperature may promote the spread of MSX, Dermo and others diseases • Sea temperature and CO2 concentration favor alghal blooms in combination with increased nutrient run-off • Sea temperature may exacerbate condition of poor water oxygenation	strenght the waves hitting the coast • Increasing water levels and wave heights • Stress on fish immune systems • Possible developments of hypoxic and anoxic conditions • Higher tempe actually favor toxic alga • Inundations • Erossion • Saltwater intrusion in aquifer • Increasing salinization in rivers and bays	
Sea-level rise[12]		• Inundation • Erosion • Saltwater intrusion in aquifers • Increased salinizatio n of rivers and bays	• Habitat loss (wetlands) • Reduction of light penetration may impact abundence and distribution of sea-grasses • Economic damages • Salinization of aquifers • Inundations of coastal landfills or other waste disposal sites • Disruption of urban drainage systems of wastewater treatment facilities

1.4. ***Practical class 1.*** Social dimension of coastal areas. The economic dimension of coastal areas. Natural capital of coastal areas

1.4.1. The economic dimension of coastal areas in ECA

Establishing the relevance of coastal areas to the economy of a country is a more complex exercise. Fisheries do not constitute a great share of GDP in ECA basins. Fishery landings within a country EEZ [4] account for less than one percent of the GDP. Buys *et al.* (2007) examined a subgroup of ECA coastal countries and suggest that a SLR of one, two, or three meters would only affect between 0.13% and 1.99% of a country's GDP (Table 1.3). Georgia and Ukraine are predicted to be the worst off, followed by Estonia. Bulgaria and Romania are predicted to be the best off.

Table 1.3. Percent of GDP affected by a sea-level-rise of 1, 2, or 3 meters [2]

% GDP Affected

Locatia	SLR (1m)	SLR (2m)	SLR (3m)
Estonia	1.3	1.42	1.53
Georgia	1.44	1.72	1.99
Poland	0.72	0.79	0.85
Romania	0.51	0.53	0.56
Ukraine	1.26	1.4	1.54
Turkey	0.7	0.9	1.1

Source:Buys et al. 2007

"The source study (Buys *et al.* 2007) has been object of criticism and this data may provide only a rough indication of the actual GDP affected. Firstly, model projections of sea-level-rise based on Intergovernmental Panel on Climate Change (IPCC) scenarios are between 0.09 and 0.88 meters by 2100; forecasts of two and three meters appear to be biased toward catastrophic previsions. Secondly, the study overlays sea-level-rise projections on a static socioeconomic system, and does not consider future development trends. This is a major shortcoming considering that coastal development is progressing quickly in ECA basins. Tourism is on the rise in the Mediterranean, Black, and Baltic Seas, and coastal tourism is expanding particularly in Ukraine, Russia, Romania, and Georgia. According to the World Tourism Organization (UNWTO) Turkey, Russia, Ukraine, Poland, and Croatia rank among the top 25 tourism destinations in the world.

These basins are the sites of important port cities (e.g. Constanza, Odessa, and Sevastopol in the Black Sea) and represent key routes for the shipping of oil and gas from Asia to Europe."[2]

1.4.2. Natural capital of coastal areas

"In addition to economic and social values, the fifteen coastal countries of the region are important from a biodiversity conservation standpoint (Table 1.4). Croatia, Albania and Turkey are part of the Mediterranean basin hotspot, and the entire Caucasus (including parts of Russia and Turkey) makes up the Caucasus hotspot."[4], [5]

Table 1.4 Number of Ramsar3 sites and Marine and Littoral protected areas for the coastal ECA countries.

Country	RAMSAR areas	Marine and litoral protected areas
Albania	3	7
Azerbaijan	2	3
Bulgaria	10	1
Croatia	4	18
Estonia	11	N/A
Georgia	2	2
Kazahstan	1	1
Latvia	6	1
Lithuania	5	3
Poland	13	6
Romania	5	8
Russia	35	47
Turkey	12	14
Turkmenistan	N/A	N/A
Ukraine	33	17

Source: Ramsar Sites Database: Earth Trends Searchable Database

Figure 1.4 shows ecosystem service product (ESP) as a percentage of GDP. "ESP can be defined as the total value of ecosystem services and products of the different ecosystem types" in coastal areas (Martinez *et al.* 2007). This is an estimate of the "non-market" value for goods and services provided by the coasts: food, salt, minerals, oil, construction materials, shore protection against storms, cycling of nutrients, water purification, recreation, etc.

The very high number provided by Martinez *et al.* (2007) for the Russian Federation may be the result of several very important goods and services provided by the long coasts of Russia (37,653 kilometers):

Arctic tundra controlling atmospheric CO_2, productive fisheries of the Barents and Bering Seas, numerous coastal wetlands providing storm protection, nutrient cycling and biodiversity conservation services, and raw materials provision.

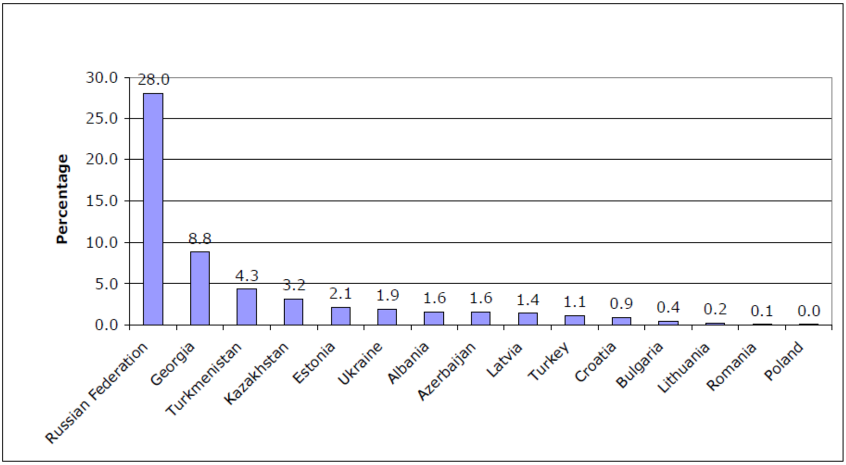


Figure 1.4 Ecosystem services product (ESP) as a percentage of national GDP. ESP represents the non-market value of ecosystem goods services delivered by the coastal zone.

1.5. *Lab 1.*<u>Description for different cases studies of coastal areas</u>

1.5.1 Baltic Sea

1.5.1.1 Weather observations in the 20th century

The Baltic is an area of great weather variation, daily and annually, mainly correlated with the patterns and strength of the North Atlantic Oscillation (NAO). However, in the last few decades some climatic trends have been detected, which do not match with the patterns of NAO, and are therefore consistent with a changing climate.
Regarding long-term gradual changes, a warming trend has been registered in the Baltic greater than the global averages, 0.08 °C increase per decade versus 0.05 C globally (HELCOM 2007). The overall results in the basin have been an increase in the growing season and in the length of the frost-free season; the ice season (the period of the year when ice covers the sea) has been reduced to between 14 and

44 days in the 20th century (HELCOM 2007). In rivers and lakes, ice thickness has decreased by up to twenty percent in the past 40 to 50 years, and the duration of river ice coverage has shortened to/by 25 to 30 days in the north and 35 to 40 days in the south. Also, between 1990 and 2005, annual sea surface temperature has increased up to 0.8 °C in some areas (HELCOM 2007).
An increase in precipitation has been reported, mainly restricted to the northern part of the Baltic, while the south has experienced a decrease in precipitation. The increase in precipitation in the northern areas has overshadowed the general increase in temperature and caused an increase in snow cover. Conversely, in the last 50 to 70 years, the mean snow cover duration in the south has decreased in Estonia, Latvia, and Lithuania.
No significant trend has been noticed in the past century for what concerns extreme wind episodes. These are relevant for storm surges, and flooding, and therefore impacts on coastal areas, but the collected data is consistent with NAO-generated events.

1.5.1.2 Climate change projections

Projections for the Baltic presented in the climate science section of this Umbrella Report show an increase in mean annual temperatures, with greater warming in the winter with respect to the summer. Increases in winter precipitation, decreases in frost days, and longer heat-waves are also predicted, and will lead to less sea-ice cover. Run-off will vary between different regions and projections forecast an overall small increase in runoff for the Baltic (HELCOM 2007).
The Baltic Marine Environment Protection Commission (HELCOM) has produced a study (2007) on projections of climate change variables using global and regional GCM (global circulation models) based on four different Special Report Emission Scenarios (B1, B2, A2 and A1FI) using 2100 as time horizon. In summary, the study estimates that the warming in the Baltic will exceed the global mean warming up to 50% (mean atmospheric annual to increase of 3 to 5 °C). The northern areas should experience the largest warming in winter-spring, and the south should comparatively warm up less, and mainly in the summer months.
Due to the temperature increases the snow season will reduce further. Also, the sea-ice season will shorten, decreasing dramatically both in the north (1 to 2 months less) and in the central Baltic Sea (2 to 3 months less) (HELCOM 2007). The increase in sea temperature (strongest in the central and south Baltic) and the reduced ice cover (-50 to - 80 % by end of 21st century) are expected to further increase

storminess and enhance coastal erosion (HELCOM 2007). These impacts are presented in Table 1.4.

Regarding the hydrological conditions the HELCOM (2007) predictions are:

1. Increased mean annual river flow in northern catchments
2. Decreased mean annual river flow in southern catchments
3. Decreased summer river flows
4. Increased winter flows by 50%.

Hydrological conditions vary regionally and locally. Temperature increases influence snow volumes along with geological features, evaporation, and changes in precipitation.

These conditions then alter the timing and volume of run-offs.

Sea-level-rise conditions are expected to depend mostly on a combination between global sea-level-rise, the “uplift of the Scandinavian plate” on the north, and the lowering of the southern Baltic coasts. Taking these factors in consideration, a sea-level-rise of 1.7 millimeters per year has been recorded in the southeastern Baltic, while a decrease in sea level of 9.4mm per year is reported for the Gulf of Bothnia between Finland and Sweden (HELCOM 2007).

SLR may increase coastal erosion particularly in the south (i.e. Poland). And an increase in windiness as projected through several GCMs could further increase these impacts but the current forecasts have high levels of uncertainty, and the magnitude of climate change impacts cannot be ascertained above natural variability as yet.

1.5.1.3 Examples from Baltic: Estonia and Poland

The best studies on coastal vulnerabilities to SLR in the Baltic have been carried out in Estonia and Poland.

Estonia

The effects of climate change, in particular sea-level-rise and increased storminess, have been studied in seven different sites, covering the most characteristic Estonian coastal areas (Kont *et al.* 2008; Kont *et al.* 2003).

The low-lying and mostly sandy coast of Estonia is highly sensitive to sea-level-rise, flooding, and erosion. Historically, the Estonian sea level has fluctuated due to changes rise has been recorded. This may be due to a combination of local weather conditions and to tectonic uplift, that in the area is between 1 and 2.8 millimeters per year (Kont *et al.* 2008). Despite this, in the past decades erosion rates on sandy beaches have increased, probably as a result of increased storminess linked to sea warming and to the reduction of sea-ice cover, particularly during the winter.

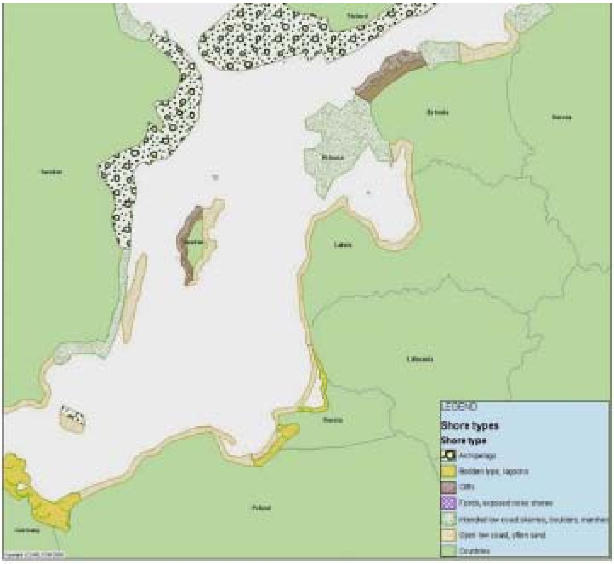
The geological characteristics of the coast (Figure 1.5a), and the low relief makes the natural system of Estonia particularly sensitive to storms, consequent flooding, and erosion. Kont *et al.* (2003) assessed vulnerability of Estonian coasts in terms of natural and socioeconomic systems, considering a one meter global SLR taking place between 1990 and 2100.

Taking into land uplift consideration, the western shores (including the Hiiumaa island) would be exposed to wetland inundation, extensive flooding leading to loss of reed beds, coastal meadows, lagoon ecosystems, spawning trout grounds, and breeding grounds of migratory birds, including grouse (Figure 1.5b). The Matsalu bay (the bay depicted in green at the center of the western Estonian coasts, Figure 6b) is home to Ramsar sites and important bird areas, and it would be particularly impacted by flooding and storm events.

Differently from most of Europe, the Estonian coasts are scantily populated and, with the exception of few harbors, coastal settlements are on higher elevations and further inland.

Therefore, the sensitivity of the socioeconomic system is presently very low, and moderate SLR does not represent a threat. The only two vulnerable sites are the city of Tallinn (the capital of Estonia) and the Sillamae industrial center. The latter is the dumping site for radioactive wastes of a former uranium enrichment plant. These wastes regularly leach into the soil and water and are separated from the sea by a narrow dam.

Increased storminess and sea-level-rise could result in a massive quantity of radioactive material being flushed directly into the Baltic. The city of Tallinn is one third protected by seawalls and groins, but the defense system will require adjustments due to the increased storminess. In general it seems unlikely that climate change will bring great harm to Estonian coasts; however, the conditions may change in the future as the country is registering an increased interest for coastal development, partly for tourism purposes.



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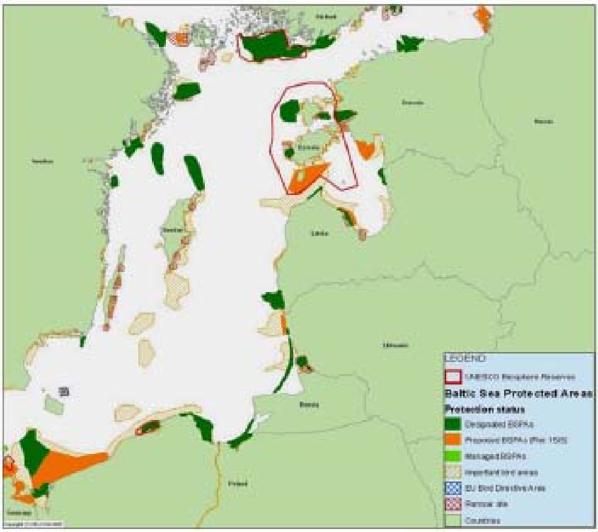

Figure 1.5

a Baltic coast typology. Estonia has low coasts especially in **b**, areas of Baltic biodiversity interest.

Source: HELCOM GIS.

The ports of Swingujscie and Ustka are of national importance and are also in sensitive areas. However, the central regions of the Polish coast ecosystems are the most vulnerable to flooding, and include lagoons, important bird areas, and a UNESCO biosphere reserve (Figure 1.5b).

Poland

Studies based on GCM models have predicted an increase in temperature for Poland, along with increased frequency and strength of storm conditions (Pruszak and Zawadzka 2008). Measurements begun in the 19th century also show a trend of increasing sea level through a combination of global SLR forecasts and local observations; Poland coasts are projected to see an increase in sea level of 45 to 65 centimeters by 2100 (Pruszak and Zawadzka 2008).
Poland's coasts are low-lying and mostly sandy (Figure 6a) and they are historically exposed to flooding and erosion (coastal defenses have been built since the 19th century).
These events have been increasing since the 1970s as a result of sea-level-rise, increased storminess and sediment starvation caused by regimentation of rivers.
Pruszak and Zawadska (2008) point out that the socio-economic vulnerability of the coasts (without considering adaptive measures) is particularly high at the eastern and western extremities of the Polish coast. The cities of Gdansk, Gdynia, and Szczecin are of particular industrial, economic, and social importance and are in proximity to the main areas of flooding: the lagoons and lowlands of the Odra and Vistula deltas (Figure 1.6)(*Source*: Pruszak and Zawadska 2008).

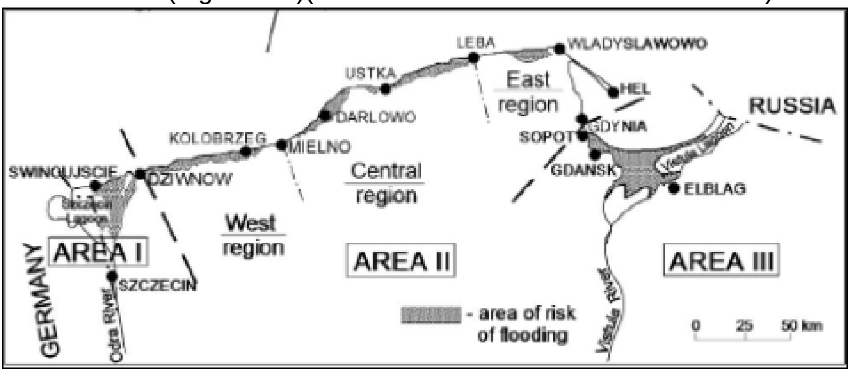

Figure1. 6 Areas at risk of flooding on the Baltic coasts of Poland. The Odra River to the east scores the border with Germany.
The Russian border is at the top right corner of the map.

Sensitivity could increase as coastal development is on the rise since the 1990s, following growth in national GDP.

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Chapter 2

EXPOSURE AND SENSITIVITY IN AREAS OF COASTLINES

2.1. The elements of vulnerability in coastal areas

- ***Exposure***

Exposure refers to the natural hazards affecting coastal areas. The hazards belong mainly to three broad categories:
1. *Discrete hazards* (also referred to as extreme events)
a. Storm surges
b. Extreme rainfall events or droughts in upstream terrestrial areas
2. *Continuous hazards* (changing averages)
a. Sea-level-rise
b. Gradual increase in air and water temperature
c. Acidification of seawater
3. *Increased weather variability, in terms of storm seasonality, frequency, and intensity, and changes in run-off quantity and seasonality*.

- ***Sensitivity***

The biophysical and socioeconomic properties of a system are the *determinants* of sensitivity of the system to climate change, and determine the magnitude of the outcome (impact) of a physical hazard (Brooks *et al.* 2005).
• *Generic determinants:* mediate sensitivity to a broad range of hazards including non-climatic ones (e.g. poverty and inequality levels or the general health of the population apply to coastal areas as well as to other systems and range of hazards.
• *Specific determinants*: mediate sensitivity for particular hazard types. For instance, the topography of a coast is a determinant specific for the sensitivity to sea-level-rise and storm surges; given a magnitude of exposure, a particular cliff height might result in a low or high sensitivity

of the coast to that hazard. This is intuitive, as a higher cliff provides more protection to human settlements.
Another example is the quality of housing; this can be a determinant specific for sensitivity to floods and windstorms (Brooks *et al.* 2003).

- ***Adaptive capacity***

The UK Climate Impact Programme (2003) defines adaptive capacity as "the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptation can be spontaneous or planned, and can be carried out in response or in anticipation of changes in climatic conditions." Adaptive capacity is therefore a combination between the availability of policy and technological adaptation options, and how fast they can be implemented. Adaptive capacity can be both at the country and local levels: quality of corruption control and effectiveness of regulatory environment, access to health care, education and information, and presence of social networks.
It is important to stress the difference between sensitivity and adaptive capacity. For instance, coastal population density is a property of the system and as such mediates the impact of a hazard. On the other hand, the level of expenditure for coastal protection structures is a way to reduce the threat and as such is part of adaptive capacity.

2.2. Exposure and sensitivity to hazards in coastal areas

Coastal areas are complex environments where natural and socioeconomic systems are deeply intertwined. Therefore, before investigating exposure, sensitivity and adaptive capacity in the ECA region, it is necessary to clarify how these definitions apply to the specific context of coastal areas.
Table 1 focuses on the different coastal dimensions of exposure and sensitivity.
Proceeding from left to right, the climatic hazards initially affect the natural system and the magnitude of floods, erosion, etc. (Outcome I) are mediated by the sensitivity of this system. For instance, the magnitude of erosion caused by sea-level-rise depends on geological features of the coasts, in particular on the relief and geology (beaches versus rocky reefs). Similarly, the extent of flooding caused by extreme rainfall events in the upstream catchments is mediated by the state of

the basin, its hydrogeological characteristics and water resources in the aquifer.
The biogeophysical events triggered by climate change hazards, and mediated by the sensitivity of the natural system (*first level sensitivity*) affect a range of natural and socioeconomic coastal sectors. The magnitude of the impacts on the socio-economic system (Outcome II) depends both on the type and the magnitude of the hazards hitting the system (the Outcome I) and on its second level sensitivity. The latter is often calculated based on the social and economic importance of coasts as measured by a range of indicators: population density, economic importance of fishery activities, and industries like tourism and shipping. The division in sectors helps to identify all the activities and elements that could be affected by hazards.
Extreme events, sea-level-rise, and changes in precipitation all cause second level outcomes (Outcome II) that include damages to housing, industrial, and transport infrastructure. Human health can be affected due to damages to water treatment systems and waste disposal sites. Also, ecosystems can be damaged; sea storms may impact wetlands as saltwater infiltration into aquifers has been proven to reduce resilience of coastal forests to storms. Increases in sea temperature and acidification impact flora and fauna directly, causing consequences for biodiversity, fisheries, and aquaculture. All these outcomes are summarized in Table 2.1.

Table 2.1. Coastal dimensions of exposure and sensitivity to climate change events.

Climate change Events-exposure to hazards	**1st Level sensibility Determinants**	**Outcome 1 Biogeophysical impacts**	**Sectors exposed to Outcome 1**	**2nd Level Sensitivity Determinants**	**Outcome II Impacts on socio-economic system**
1. xtreme evnts 2. ea level rise	• Biogeological features of the coast Relief Geology Coastal landform Coastal retreat Tidal range	Erosion Beach migration Coastal dune destabilization Flood Changes inrun-off due to upstream extreme	Ecological systems Economy Infrastructure Health	Population density Number of marine coastal protected areas Fishery and aquaculture % of national GDP Revenues from tourism	Loss of lives Loss of property Damage to infrastructures Increased risk of diseas Economic losses damages

		rainfall events or droughts Inundations Saltwater intrusion		as % of GDP Historic/Cultural importance	Loss of cultural resources Forced migrations Loss of ecosystem goods and services
3. eavy extreme rainfall events in upstream terrestrial areas 4. roughts in upstream terrestrial areas	• State of the water basin Physicogeographycal and hydrological features catchment Amount of lake or groundwater storage	Erosion Beach migration Coastal dune destabilization Flood Changes inrun-off due to upstream extreme rainfall events or droughts Inundations Saltwater intrusion	Ecological systems Economy Infrastructure Health	Population density Number of marine coastal protected areas Fishery and aquaculture % of national GDP Revenues from tourism as % of GDP Historic/Cultural importance	Loss of lives Loss of property Damage to infrastructures Increased risk of diseas Economic losses damages Loss of cultural resources Forced migrations Loss of ecosystem goods and services
5. ea temperature rise 6. ea water acidification	Modeling takes into consideration necessary parameters				Direct changes to sea impacts on biodiversity, fisheries, etc.

Note:
Green colour-exposure and sensitivity of natural systems
Orange colour-socio-economic system

2.3. Exposure and sensitivity in ECA coastal lines

This section presents some details of exposure and sensitivity to climate change forcoastal areas of the basins of interest (Baltic Sea, Black Sea, Adriatic and Mediterranean Seas, Caspian Sea, and Arctic Ocean). Specific examples illustrate how hazards from sea-level-rise and storm surges result from a combination of global trends and local conditions,

including tectonic uplift or subsidence of the coasts, local weather and pressure systems, changes in river run-off and evaporation patterns. As it was not possible to obtain original modeling projections for SLR, data was collected from different literature sources analyzing different scenarios and time horizons. An effort has been made to be explicit on the source and the scenarios utilized.
In addition, some cases will be presented to describe possible synergies between climatic changes and other stressors currently affecting ECA marine basins. This is important as it must be recognized that vulnerability to climate change of both natural and socioeconomic sectors of coastal areas will depend not only on changes in climate, but also on the interaction between these and stresses like pollution, overfishing, land use change, and habitat fragmentation, along with population increase and changes in governance, economics and cultural values. These external factors affect vulnerability by impacting either the sensitivity or the adaptive capacity of the coastal area systems make (Figure 2.1).

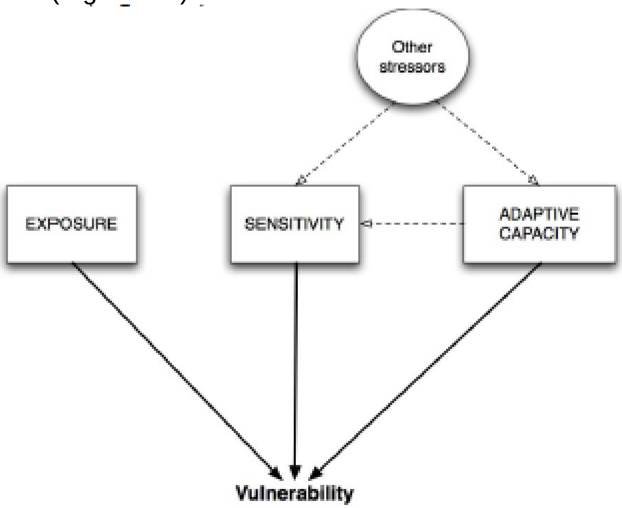


Figure 2.1 External stressors including societal and governance changes, along with environmental impacts such as pollution and overfishing affect the vulnerability of coasts to climatic changes by affecting the sensitivity and adaptive capacity of coastal systems

See examples with Baltic Sea.

2.4. ***Practical class 2***. Synergies between climate change and current stresses in the sea: eutrophication, human health, stressors, errosions, economic damages

2.4.1. Eutrophication on Baltic Sea

Eutrophication is a serious issue in the Baltic Sea. It is caused by the discharge of nutrients and sediments collected along the vast river basins feeding into the sea, and it is worsened by the slow water exchange with the North Sea. Extensive blooms of algae and cyanobacteria have been reported in the since the 19th century, but in the last decades they have increased in duration, frequency, and biomass (Bianchi *et al.* 2000).

Run-off into Baltic Sea is predicted to increase over this century due to enhanced precipitations related to climate change (HELCOM 2007).

ECA countries in the south of the Baltic basin are likely to be exposed to a higher risk of flooding which will contribute to leaching of nutrients into the sea. Because run-off accounts for up to 97% of the nutrient influxes from the land to the sea in the Baltic area, it is assumed that increased run-off will translate into a greater input of nutrients, and possibly exacerbate eutrophication events (HELCOM 2007).

In addition, surface sea water in the Baltic has been warming for the past fifteen years and the trend is projected to continue (HELCOM 2007, Alcamo et al. 2007). Assuming a concurrent increase in nutrients, the combination of these two factors may result in enhanced phytoplankton growth. An increase in frequency and intensity of these events raises concern as several species of cyanobacteria carry toxins harmful to human and animal health.

Warming may exert selective pressure limiting the growth of cold-water species like diatoms while favoring warm water species like the toxic Nodularia. In fact, the growth of diatom and dinoflagellate species is optimal only at temperatures just above freezing, while blooms of cyanobacteria occur only at temperatures higher than 16 ºC.

Furthermore, temperature increase has an enhancing effect on cyanobacteria regardless of run-off nutrient inputs. This is partly due to the fact that cyanobacteria can naturally fix nitrogen and therefore contribute directly to eutrophication (HELCOM 2007).

Nodularia spumigena produces toxins called nodularins. These have hepatotoxic effects causing gastrointestinal illnesses and liver damage in case of persistent exposure (Hallegraeff et al. 2003). Acute toxicity is

the most direct threat, but short, chronic exposures could lead to serious health effects. For instance it is hypothesized that “cyanobacterial toxins are part of a complex of risk factors” that determine the high incidence of human hepatocellular carcinoma registered in China (WHO 1999).
Cases have been reported of death of cattle and pets after ingestion of water or scum containing Nodularia (WHO 2003) , and although there are no reported cases of human poisoning to date, the possible increase of Nodularia blooms represents a hazard for human health. The risk of exposure could be particularly high for children (WHO 2003).

2.4.2. Eutrophication on Caspian Sea

The Caspian Sea is the largest enclosed water body. It is a 1,200 kilometer–long brackish basin, and because of its north-south orientation it is subject to a variety of climatic conditions, from a continental climate on the northern shores to sub-tropic conditions in the south. In winter, sea temperatures in the north are close to 0 ºC, with large expansions of water covered in ice. In the south, temperatures are around 10 ºC.
Fluctuations in sea level have been one of the most defining characteristics of the Caspian, and they depend on both natural and human-induced factors. The Volga provides 80% of the total water inflow to the Caspian, and the outflow is mainly determined by surface evaporation. Changes in river flows and in climate temperature modify inflow and outflow, hence causing most of the sea level change. Human activities, such as damming and water abstra ction, have a smaller impact.
Climate change is likely to modify the hydrological budget17 of the Caspian Sea, and induce ariations in sea-level-rise through increased inflow from the Volga and enhanced surface evaporation from the sea itself.
Recent studies (Renssen *et al.* 2007; Elguindi and Giorgi 2007) have projected sea level change in the Caspian using climate models based on the IPCC A1B scenario for the 21st century.
The model used by Renssen *et al.* (2007) largely agrees with the Elguindi and Giorgi (2007) work, and predicts a decrease of six meters in sea level from 1975 to the end of the 21st century. Based on the simulation, the drop in level is the result of increased surface evaporation exceeding the augmented run-off from the Volga caused by enhanced precipitation in the Volga catchment basin. Because the model did not include “direct anthropogenic influences upon river

hydrology, such as water extraction and dam building" (Renssen *et al.* 2007), it is reasonable to expect an even greater drop in sea level.
A significant decrease in sea level, in combination with evaporation and increasing temperatures may particularly affect fisheries, infrastructures, human health, tourism, and biodiversity.
The reduction in ice cover, particularly in northern areas, may impact the population of seals. This species, endemic of the Caspian, uses floating ice as pupping sites and a drastic reduction of cover may negatively affect its reproductive success. Evaporation, increase in sea temperatures, and consequent changes in water salinity has the potential to impact fish stocks and put additional stress over the already imperiled sturgeon population. Furthermore, a reduction in sea level would increase costs for industry (mainly oil and gas) and transports as it would require
modification of structures and procedures in response to the new conditions.
Finally, this scenario represents a potential health hazard. The Caspian Sea has been characterized in the past by significant fluctuations in sea level, whose causes have not, as yet, been completely uncovered. They may include changes in precipitation and runoff, along with tectonic and carsic movements and other factors. Nevertheless, awareness of the unpredictability of sea level has not discouraged coastal developments from occupying new land once the sea has retreated. As a result, past rise in sea level has caused vast damages, for instance on the Russian coast (Frolov 2000; GEF 2002).
There exists the possibility that a new drop in sea level may again produce an unregulated rush to occupy newly available land. As a result, the populations would risk contact with a range of potentially very dangerous substances that are presently locked in the sediments of the basin (Figure 2.2a, b).
The increase in temperatures could also promote the generation of algal blooms, which have recently been recorded along the coastal areas of Iran (Amy Evans, personal communication), in the south of the Caspian. The formation of red tides would be a health threat, and cause damage to tourism as well as a problem for fisheries and aquaculture.

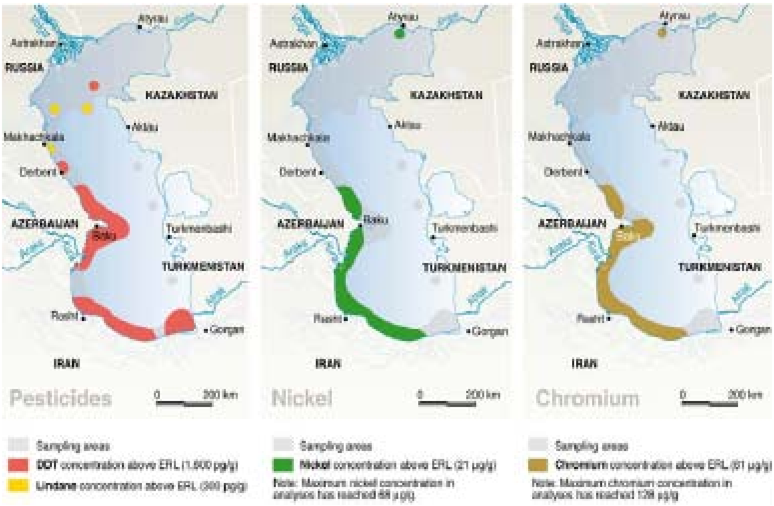


Figure 2.2a Pesticides and heavy metals in the sediments of the Caspian Sea.
Source: Erin Grid, “Erin Grid, Website,” Erin Grid

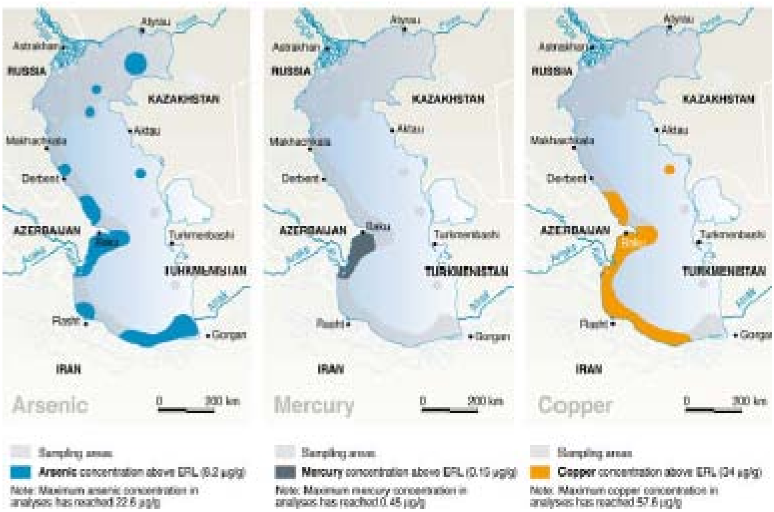


Figure 2.2b Heavy metals in the sediments of the Caspian Sea.
Source: Erin Grid, “Erin Grid, Website,” Erin Grid

2.4.3. Stressors in the Caspian Sea

As introduced above, climate change events will potentially interact with current stresses, in particular pollution and unregulated coastal development.

Industrial emissions, toxic and radioactive wastes, agricultural run-off, sewage, and leaks from oil extraction and refining are the major sources of pollution in the sea. The sources are both local and off-site. Due to its vast drainage basin, the Volga is the principal contributor of Caspian nutrients and the projected increased run-off (see climate science section) may amplify the risk of eutrophication and algal blooms in the shallow northern part of the sea.

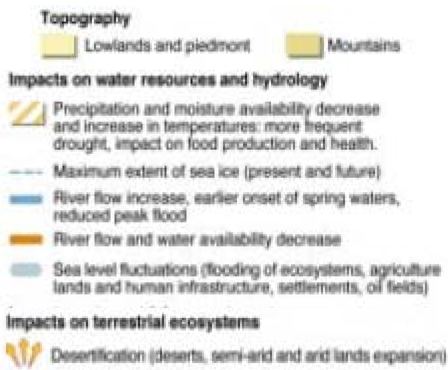
Other impacts include overfishing and habitat destruction in coastal areas, the latter due mainly to damming and construction of hydroelectric plants on the Volga. The combination of climate change and current stressors has the potential to impact fisheries, human health, and biodiversity.

Figure 2.3 shows some other climate change impacts described in the sources listed at the bottom of the figure itself. In case the projections described above would turn out to be inaccurate, or simply wrong, and the basin experiences a rise in sea level rather than a drop, the map shows areas at highest risk of inundation. The peninsula of Baku, site of important oil and gas industries, would be one of the most severely affected.

Increases in temperature around the basin are also likely to extend arid conditions, with impacts mainly for agriculture production.”[1]

Figure 2.3 Possible impacts from climate change in the Caspian Sea basin.
Source: National Communications from Iran, Azerbaijan, Armenia, Kazahstan, Russia, turkmenistan and United Nations of Framework Convention on Climate Change (UNFCCC), Yu Izmail, 1997.

Where



2.4.4. Mediterranean Sea

"Based on the projections presented in the climate science section, southeastern Europe, including the East Adriatic and the Mediterranean coast of Turkey, will experience an increase in annual mean temperatures, number of dry days, and length of heat waves, with a concurrent decrease in precipitation, frost days, and overall run-off. These events may trigger more forest fires in coastal areas, and affect river flow and groundwater supplies thereby impacting coastal agriculture, local biodiversity, and wetlands. Most of the following originating from sea-level-rise (SLR) and storms. To begin, it should be pointed out that because of tectonic activity, changes in density of deep waters, and local changes in air pressure systems, the Mediterranean is far from being the ideal place to gather meaningful forecast data on sea levels (Karaca and Nicholls 2008)."[1]

East Adriatic – Northern areas, Croatia, and Albania

- ***High Adriatic***

"From data monitoring of Venice and its lagoon, a long-term trend of rising sea level has been clearly established for the north Adriatic coast. This phenomenon is due both to global changes in sea level and to land subsidence, particularly in deltaic areas. This is exacerbated by water surges due to storms and by particularly strong winds typical of the Adriatic basin such as the Bora (cold, dry, northeastern wind) and Sirocco (southsoutheastern wind). The combination of these factors has increased the frequency and intensity of floods in the northern Adriatic coastal areas" (Valiela 2006).

Croatia

Currently there is a lack of sea level projections for the Croatian coast. Only one study has been run to date with the collaboration of UNEP-MAP and the Climate Change Group of the University of East Anglia. The modeling exercise produced projections of sea-level-rise for the 2030, 2050, and 2100 time horizons and for two locations on the Croatian coast: the island of Cres (with the main city, Losinij), and the Kastela Bay (Baric *et al.* 2008). The results are shown in the table below.

Table 2.2. Croatian SLR projections

2030	**2050**	**2100**
+18+/- 12 cm	+38+/-14 cm	+65+/-35cm

Source: Baric et al.2008

To add to the uncertainty, the East Adriatic coast is tectonically active, and observations of sea-level-rise at different locations recorded between 1956 and 1991 show great differences, with average sea level rising in one site and dropping in another (Ref.).

A United Nations Development Programme (UNDP)/Global Environment Facility (GEF) project is under way to produce the first national report on climatic changes, vulnerability, and national adaptive capacity. Because of the lack of consistency in the data, the project is conducting a qualitative assessment, based on expert judgment, of the vulnerability of coasts to 20 and 86 centimeter sea-level-rise (Baric *et al.* 2008)[2].

The Croatian coastal zone has high socioeconomic and biodiversity importance. The narrow coastal strip (1-5 km) has a population density higher than in the hinterland (Baric *et al.* 2008). Coastal tourism is a major source of revenue, with 95% of all tourists remaining on the coasts. Maritime transport and shipbuilding are important industries.

Fisheries and aquaculture have been on the rise, and agriculture is widely practiced on the coasts, particularly in the alluvial plain19 of the Neretva River. Moreover, cities of historic value are scattered all along the coast.

The high economic, social, and cultural value of Croatia's coast indicates that its socioeconomic system has high sensitivity to climatic hazards. However, from the biophysical point of view, the sensitivity of the Croatian coast to sea-level-rise and storm surges is generally low (Baric *et al.* 2008, Republic of Croatia 2006). In fact most of the coastline (including the many islands) is rocky, with few steep gravel or sandy beaches, which are little prone to erosion. The only areas potentially exposed to threats are small, uninhabited islands, the coastal plain between the cities of Zadar and Sibenik, the alluvial plain of the Neretva, and a few other areas. The current UNDP/GEF study shows that a twenty centimeter sea-level-rise would not have a significant impact. Some cities like Rovinij (on the island of Cres), Pula and Split (on the mainland) are already experiencing some flooding events and their frequency may increase slightly (Baric *et al.* 2008). It is possible that the SLR will cause minor problems to some outlets of sewerage systems, and to salt pangs. Minor flooding may also occur in the plains of the Neretva, Rasa, and Cetina rivers.

Contrastingly, a sea-level-rise of 86 centimeters would constitute a much more serious threat considering that tourism, fisheries, and shipping infrastructures are often built right up to the shore. Marinas may be seriously damaged, even if one grants that many are built on floating docks which allow them to adapt more easily to changes in water level (personal experience). The entire low-lying Istrian west

coast, and the aforementioned cities, with the addition of Dubrovnik, Omis, and Trogir, would be exposed to a much higher risk of flooding from sea rise and storm surges, and agriculture activity in the Neretva alluvial plain may be seriously impacted.
Vulnerable spots include two freshwater lakes (both named Vrana), one on the Cres Island and another close to city of Biograd. Saltwater intrusion may occur in the latter (used for irrigation in agriculture), as the lake is very close to the shore, and the short land strip that separates it from the sea is of high porosity, karstic in nature (Baric *et al.* 2008). However, in general it is not possible to assess the effects of sea-level-rise on saltwater intrusion along the Croatian coast because there is no available data on current groundwater table levels or soil permeability.
In summary, SLR effects in Croatia will be localized; it is more complicated to assess the risk to the 1,185 islands, some of which are of high historical, biodiversity, and tourism value.

- ***Albania***

The socioeconomic system of the Albanian coast is highly sensitive to flooding and increased storminess. This is mainly a result of unregulated urban development that has allowed building right up to the shoreline, exposing infrastructures to a high risk of damages (World Bank Staff, personal communications).
Considering a 2100 time horizon, “a sea-level-rise of 48-60 cm would result in direct flooding of coastal areas” and significant saltwater infiltration (Republic of Albania 2002), whereas the projections for 2050 (20 to 24 cm) will not have major impacts. SLR particularly threatens beach areas in the northern and central zones of the Adriatic.
People, infrastructure, tourism (hotels), roads, and agricultural lands are vulnerable.
Again considering the 2100 time horizon, the Republic of Albania National Communication to the UNFCCC (2002) identifies particularly vulnerable areas affected by land subsidence (Shengjin, Kune-Vain, Tale, Patok, Ishem), roads like the new Fushe Kruje- Lezhe, and former swamps (Durres, Myzeque, Narta, and Vrug). It is also expected that wetlands will be threatened by the reduction of stream flow which is likely to result from the reduction in run-off projected for the region.

- ***Mediterranean coast of Turkey***

The Mediterranean coast is diverse both from geomorphological and socioeconomic points of view.

Karaca and Nicholls (2008) affirm that “there are no reliable long-term sea-level measurements in the eastern and southern Mediterranean.” However, based on global projection from several studies, and anecdotal evidence, it is expected that sea-level-rise and storm surges will especially impact tourism and agriculture along the Mediterranean coasts of Turkey. The impacts are likely to be localized, as in general the geophysical characteristics of Turkey’s coastline indicate a low vulnerability to SLR (Republic of Turkey 2007).

Turkey has tectonically active, high-elevation terrain (85% of Turkey is above 450 meters). Black Sea coasts included, 69% of Turkish coasts are rocky, 19% sandy, and the remaining 12% are swampy deltaic plains often comprising wetlands and lagoons.

According to the vulnerability study by Karaca and Nicholls (2008), these low-laying areas are the most vulnerable to flooding, erosion, and saltwater intrusion assuming a one meter SLR and storm surges. Several deltaic plains (e.g. Gediz, Seyahn and Ceyhan) are particularly vulnerable because of land reclamation for agricultural purposes (Karaca and Nicholls 2008).

While the Black Sea coast of Turkey provides most of the tonnage of the fishery industry, the Mediterranean coasts and the coasts of the Marmara Sea are most important for the tourism industry. This sector has a high growth rate and increasing sensitivity to SLR as most of the newly developed accommodations are built right up to the shoreline.

Moreover, tourism drives most of the large increase in urbanization toward the coast and large coastal cities like Izmir, Adana, Antalya, and Alanya on the Mediterranean, and Istanbul on the Marmara. The increase in population in coastal cities significantly amplifies the sensitivity of the socioeconomic system to sea-level-rise. Istanbul is a the shore, and the city by itself accounts for 21% of the national GDP. The major threats are actually from saltwater intrusion, particularly to two coastal lagoons and to Terkos lake, the freshwater supply of the city (Karaca and Nicholls 2008).

The overall vulnerability of the Turkish coastline to SLR is estimated to be low to medium. However, increases in economic development are expected to increase the overall sensitivity. Several important sites are going to be significantly affected, particularly Saros bay, and the eastern Mediterranean (Hatay Yumurtalik, Iskenderun).

Storms are also already heavily affecting the Izmit-Glolcuk bay in the Marmara Sea, Izmir Bay in the Aegean Sea, and the Fethiye and Antalya gulfs in the Mediterranean.

Damages are projected to increase in absence of an adaptive response. Furthermore, sensitive cultural and historical sites in Istanbul, and on the Aegean and Mediterranean coasts, like the ancient Greek cities of Phaselis and Patare, are already threatened by wave action.

2.4.5. Black Sea

At present there is a serious lack of studies addressing possible climate change trends in the Black sea region, and a lack of consistency in the few existing reports.

Regardless, a recent article has focused the attention on some climatic changes along the southwestern coast (Bulgaria and European side of Turkey) of the Black Sea (Alexandrov *et al.* 2005). This modeling study, based on the A2 and B2 IPCC scenarios, projects that in the 21st century the western coast of the Black sea will experience an increase in the trends observed during the last two decades of the 20th century, particularly in freshwater shortages originating from increasing temperatures and droughts, decreasing precipitations, decreasing run-off, and diminishing groundwater levels.

Although the A2 and B2 scenarios do not show complete agreement in the rate of change, they do agree on predicting increasing warming until 2080, with temperatures that increase by 7to 8 ºC by the end of the century under the A2 scenario. The model also pointed to a trend that can lead to a decline in precipitations of up to 70%. As this area of the Black Sea is important for the agricultural sector, an increase in demand for irrigation has to be expected. This is expected to clash with the overall reduced water availability.

Valiela (2006) reports that the rate of sea-level-rise has been higher in the Black Sea than in the Mediterranean (27 ± 2.5 mm per year, versus 7 ± 1.5 mm per year), and this has repercussions both on urban centers, infrastructures and wetlands. For instance, the Bulgarian coast is mostly flat and therefore physically sensitive to SLR; the overall vulnerability is high because of the unregulated development. Increased erosion and flooding would negatively affect tourism assets, infrastructures, and the energy sector through impacts on coastal oil and gas refineries (Milen Dyoulgerov World Bank Staff, personal communication).

Because coastal areas in Bulgaria, Ukraine (chiefly Crimea), and some parts of Georgia are already affected by chemical and/or wastewater contamination, inundations would likely exacerbate coastal pollution. Furthermore, SLR and storm surges could have an impact on the erosion affecting the Black Sea coast between Turkey and Georgia, exacerbated because of unlawful urbanization, sand mining, and poor judgment in site selection, design, and construction of coastal structures, especially harbors (Yuksek *et al.* 1995).

Karaca and Nicholls (2008) report tide gauge data collected from 1930 to 2000 for the following cities: Varna (Bulgaria), Constantza (Romania), Sevastopol (Ukraine), Tuapse (Russia), Pito (Georgia), and Batumi (Georgia). The relative sea-level-rise over 70 years is 3.7 millimeters per year for Pito, 6.8 millimeters per year for Batumi, and 1 to 2 millimeters per year for the other cities, which is consistent with global trends. The results seem to indicate that the Georgian coast is subsiding with respect to the rest of the Black Sea basin. The Russian coast will be particularly vulnerable to erosion due to high economic activity and development of coastal tourism; it is also expected that several large cities along riverbanks will be impacted (Frolov 2000). It is expected that at this rate cultural and industrial areas will be flooded and salt water will infiltrate coastal aquifers. For its part, Ukraine is already experiencing erosion problems that caused the loss of housing, arable land, industrial sites, and traditional spas and resorts for mud treatment important to the tourism industry.

Sea-level-rise for the Black Sea coast of Turkey has been estimated at 1 to 3 millimeters per year (Karaca and Nicholls 2008). Flat areas vulnerable to sea-level-rise and storms are rare, and are represented mainly by deltas and lagoons (19% of Turkish lagoons are on the Black Sea). The major deltaic areas are the Yesilirmak, Kizilirmak, and Sakarya.

The first two would be particularly sensitive because of agricultural development.

Despite a generally low vulnerability of the biophysical system, a sea-level change of this magnitude would significantly impact the coastal socioeconomic system. Similarly to the Mediterranean coast, the Black Sea coasts have high population density concentrated in coastal cities. Population livelihood is based on fisheries and agriculture, and both activities are going to be affected by sea-level-rise. In the year 2000, 76% of the Turkish fishing tonnage came from the Black Sea. The industry is already threatened by overfishing and pollution, so climate change could worsen the situation.

Storm surges already affect some settlements (Karaca and Nicholls 2008) and worsening conditions may bring damages to the 23 ports along the Black Sea. Furthermore, storms, erosion, and sustained flooding are predicted to damage the very important shoreline east-west road system that runs along the coast.

The Black Sea is a very important source, refinement point, and transport route for oil and gas. There is a concern that oil and gas refineries and infrastructure (e.g. in ports like Batumi) will be impacted by SLR, increased storminess, and erosion on the Russian, Bulgarian, Ukrainian, and Georgian coasts.

- ***Stressors in the Black Sea***

The coasts of the Black Sea share most of the problems affectin affecting the Baltic. Three main
stresses have caused major degradation of its natural resources:
1. Water pollution: eutrophication/nutrient enrichment (sewage and inorganic nutrients), and chemical pollution (including oil and other industrial pollution)
2. Biodiversity changes: introduction of alien species
3. Unsustainable use of natural resources: overfishing.
Many rivers open up into the Black Se, and transport sediments, nutrients, and chemicals collected over vast drainage basins. Three of the four biggest rivers in Europe end in the Black Sea, and the Danube (the second biggest) has a basin that covers most of central Europe. Exactly like in the Baltic the ensuing eutrophication problem is exacerbated by the enclosed nature of the basin, and by its slow water exchange with the Mediterranean.
Despite the 20% reduction in nitrogen emissions from the Danube in the last ten years (GEF 2007), agricultural and livestock wastes are still an issue, and eutrophication may be worsened by rising temperatures in the Black Sea (Figure 2.4) [1].

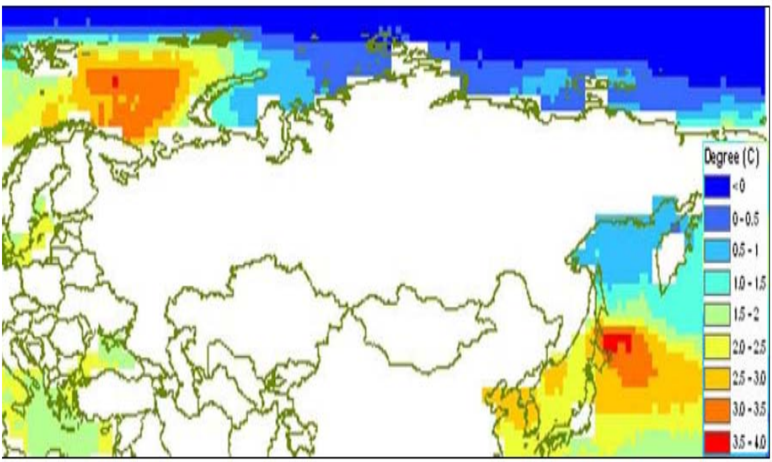


Figure 2.4. Sea temperatures are rising across the Baltic, Black, Mediterranean, and Arctic Seas [1]

Rising temperatures and eutrophication may lead to an expansion of anoxic areas with consequent impacts on fisheries and tourism. The fishery sector has already suffered greatly in terms of reduced catches, mainly due to overexploitation and introduction of exotic species. In the mid 1980s, the wart comb jelly *Mnemiopsys leidyi* (Phylum Ctenophora) was accidentally introduced in the Black Sea (most likely through the ballast water of ships), and caused a collapse in catches by predating on fish larvae and on their preys. The spread of other exotic species may be favored even more by the warming of the sea.
Sea-level-rise and increased storminess represent an additional threat with respect to chemical pollution. Coastal landfills have been identified as pollution hot-spots in the Black Sea (GEF 2007)[5]; in areas like the coasts of Georgia sea-level-rise and coastal erosion may further damage these landfills and incease the amount of pollutants flushed to sea (Darejan Kapenadze World Bank Staff, personal communication).
Finally, the damming and channeling of rivers, along with ill-managed coastal development are responsible for alteration of the sediment balance, distribution, and a resultant erosion problem. In Russia, Bulgaria, Ukraine, and Georgia there is a major issue with unregulated construction close to the shore.

2.4.6. Arctic – Russian coasts in the Arctic

The Arctic is one of the areas most vulnerable to climate change. Arctic *vulnerability* may increase due to its rising socio-economic importance. The IPCC (2007) reports that from 1980 to today the arctic has had the highest warming rate, with an increase of approximately 1 ºC per decade in the winter and spring months. Future changes will have a major impact on the arctic ecosystem and biodiversity and will modify the availability of natural resources.
Declining snow cover and increasing precipitations are expanding the river flow and the amount of run-off into most of the Arctic Ocean (Anisimov *et al.* 2007)[3]. This, in combination with the melting of glaciers and the retreat of summer sea ice cover is driving a global rise in sea level that along the arctic coasts has been measured at between ten to twenty centimeters in the past century, and is projected to grow of additional ten to ninety centimeters over the course of this century (ACIA 2005) [4].
On the arctic coasts of Russia, sea-level-rise is already accelerating erosion rates. The process will be exacerbated by the thawing of the permafrost, which makes the soil less resistant to wave impact, and by

the reduction in sea ice, which allows higher, stronger waves and storm surges to hit the coast. Erosion, flooding, and receding coastlines will impact both natural and socioeconomic systems. Flooding and storm surges are already threatening wetlands, settlements, and industrial facilities, some of which will be forced to relocate. Thawing of land ice and permafrost will threaten the stability of buildings and industrial installations like oil and gas pipelines, while at the same time damaging roads and shortening the periods when ice roads can be used for travel, thereby disrupting transport and making communications more difficult and costly (ACIA 2005)[4].

On the positive side, the reduction in sea ice will likely open new shipping routes in the arctic, and increase marine transport and access to resources like gas and oil. The opening of a northern passage is likely to shift trade routes, change trade links and transportation networks, and generally trigger major development. This will undoubtedly raise sovereignty and environmental concerns that will need to be addressed (ACIA 2005) [4].

2.4.6.1.1 Destabilization of the arctic coasts, erosion, and economic damages

The arctic is exposed to a range of environmental impacts of human origin, including pollution, overharvesting of natural resources, and habitat conversion (see biodiversity section). Warming of the climate is expected to boost the drilling operation for oil and gas and consequently more infrastructures and facilities will be built.

This type of development will need to be regulated and will need to take into consideration synergies between operations on the coasts and sea-level-rise. Past failures to do so are already inflicting damages and raising costs for industry. The oil storage facility at Varandei on the Pechora Sea, on the southeastern part of the Barents Sea, exemplifies the consequences of synergy between impacts on the local environment and climate change. The area is geologically fairly stable, however industrial constructions have damaged the natural environment and reduced the stability of the coast so that the erosion rate is twice as fast than in areas free of human activity (Ogorodov 2004)[6].

Coastal retreat combined with the ensuing direct effects of increasingly strong storm surges and sea-level-rise have already damaged facilities and housing and are threatening the airport area. The problem will be exacerbated further as the climate continues to warm while sea ice cover decreases, giving way to stronger waves and greater sea-levelrise (ACIA 2005).

2.5. ***Lab 2.*** How can us combat climate change. Movies.

- How can us combat climate change [10], [11]:

https://www.planning.org/planning/2021/spring/three-movies-that-can-help-us-combat-climate-change/
http://www.kristinohlson.com/books/soil-will-save-us

- How movies are helping young people fight climate change and other global challenges [12]:

https://www.weforum.org/agenda/2021/07/movies-climate-change-awareness/

- 6 MUST-SEE MOVIES ABOUT CLIMATE CHANGE [12], [13]:

https://www.climaterealityproject.org/blog/6-must-see-movies-about-climate-change

Truly great films about the climate crisis are tough to come by. Allusions to environmental destruction are very familiar in the futuristic dystopias Hollywood churns out like clockwork, but they rarely get the science right – or they abandon it entirely in favor of skipping straight to some post-apocalyptic CGI extravaganza.
Those of us with a little knowledge of the climate crisis bristle at this kind of doom-and-gloom bombast – because we know better. But that doesn't mean a few thoughtful films haven't been able to cut through the noise.

- **INTERSTELLAR**
- **BEASTS OF THE SOUTHERN WILD**
- **CHASING CORAL**
- **SNOWPIERCER**
- **AN INCONVENIENT TRUTH/AN INCONVENIENT SEQUEL: TRUTH TO POWER**
- **ARE YOU READY TO FIGHT?**

- The best new documentaries about global warming [14]:

https://yaleclimateconnections.org/2020/03/seven-of-the-best-new-documentaries-about-global-warming/

- **After the Fire [14]**
- **Blowout: Inside America's Energy Gamble** [14]
- **The Condor and the Eagle [14]**
- **Last Call for the Bayou: Five Stories from Louisiana's Disappearing Coastline [14]**
- **Lowland Kids [14]**
- **Mossville: When Great Trees Fall [14]**
- **The Story of Plastic [14]**
- **The pollinators [15], [16]**
- **The hottest August [15], [17]**
- **The Last Trap Family [15], [18]**
- **The last man fishing [15], [19]**
- **Recipe for disaster [15], [20]**
- **Thirteen Ways [15], [21]**
- **The Seer and Unseen [15], [22]**
- **Kifaru [15], [23]**
- **Anthropocene: the human epoch [15], [24]**
- **Fast Color [15], [25]**

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Chapter 3

ADAPTIVE STRATEGIES AND CAPACITY IN THE CONTEXT OF COASTAL AREAS

3.1. Adaptation strategies

Climatic changes both aggravate old issues and bring new threats to coastal zones.
Models predict that damages will increase if adaptation measures are not implemented.
Today, as in the past, experts and stakeholders most frequently resort to protective measures against storms and sea-level-rise. The coast of Poland is protected by more than 200 kilometers of hard structures that began to be put in place in the 19th century. Similar hard structures, as well as dunes, have been adopted along the coasts of Turkey, mostly on the Black Sea side.
Given the scale of the climatic phenomena and the extent of the territory likely to be affected, hard structures are not an economically viable solution. Besides, barriers are known to modify local currents and sedimentation patterns with the result being a mere shift of erosion problems elsewhere along the coast. In some cases protective structures will still be necessary, for instance to defend important historical port cities in Croatia (Dubrovnik, Split), or possibly for cultural sites like the ancient Greek cities of Phaselis and Patara in Turkey. However, the consensus is that the climate change challenge should be used as an opportunity to adopt a long-term strategic approach to coastal management; this is reflected in some of the adaptation options described in
Coastal areas have always been known as dynamic systems, shifting between different states. However changes are now occurring more rapidly and are affected by events characterized by a high level of uncertainty.
As a result, we must prepare both for projected changes for the unexpected. Adoption of an *adaptive management* approach is crucial to deal with the uncertainty of complex climate change events. Here,

adaptive does not refer to reaction or preparation to climate change, but to a management framework based on implementation, monitoring, and periodic reassessment of adaptation measures (Table 3.1 [1]); it requires that the measures against climate change have clearly defined, measurable goals and carefully planned monitoring systems, so that the observed failure or success will allow us to learn more about our changing environment and hone the adaptation solutions (description).

Table 3.1.Adaptation measures organisez by impact [1]

Biophysical events	**Anticipatory-planned adaptations**	**Actors in charge of the meassures**
Erosion	Protect-Accomodate-Retreat Beach nourishment Wetland protection and restaurations Revised spatial planning and water resources management Detailed vulnerability assessment	Ministry of Environment or Infrastructure provides guidelines and legal frameworks Some implementations can be done through local authorities in collaboration with the private sector and the public-of-large Vulnerability assessment ussualy contracted to scientific institutions often reporting to the Ministry of Environment
Inundations	Protect-Accomodate-Retreat Beach nourishment	Ministry of Environment or Infrastructure provides

	Wetland protection and restaurations Revised spatial planning and water resources management Detailed vulnerability assessment Water inundations forecast and warning system Preparation and implementation of an emergency preparedness plan Awareness raising campain-hazard awareness education Disaster risk insurance and weather risk hedging instruments	guidelines and legal frameworks Some implementations can be done through local authorities in collaboration with the private sector and the public-of-large Vulnerability assessment ussualy contracted to scientific institutions often reporting to the Ministry of Environment HydroMet institutions are in charge of wether forecast Ministry of Interior is in charge of preparedness plans and cordonates with local and regional authorities, civil protection and fire departments Awareness campain usually managed by Ministry of interior or Education Disater risk insurance

		managed by private sector, professional market players,and sometimes ministry of Finance Constractions or retrofitting codes come from central government Central governments acting under transboundary international agreements and international organisations
Floods	Increase public awareness of floading- hazard awareness education Flood forecast system Warning system Revised spatial planning, retroffiting of buildings and water resource management Watershed modeling exercise with hydrological models that keep climate change into	-Ministry of education in collaboration with regional and local authorities, -Floods forecast and warning systems -Center and regional government (directly) or trough local governments mandates -Scientific Institutions often reporting to Ministry of Environment -Private sector,

	consideration Disaster risks insurance and wether risk hedging instruments Regional disater task teams deployable across borders	professional market players, sometimes, Ministry of Finance
Changes in run-off	-Adaptation to drought and subsequent reduction in water quantity and quality, maintenance in the water infrastructures, reduces water losses	Ministry of agriculture in collaboration with user's asociations in charge of monitoring of the local level
Saltwater intrusion	-Revised spatial planning and water resaource management -Saltwater intrusions barriers -Injections of fresh water into aquifers	Central governments provides the legal basis and scientific institutions set standards and bring technical expertise
Sea temperature and acidification	-Monitoring systems of physico-chemical parameters -Monitoring of seasonal and geographycal locations of nutrients run-off -Promote best	-Monitoring is managed by environmental network/ministry of Environment/local authorities -Ministry of Agriculture, Ministry of Environment

	available techniques in agriculture activities -Monitoring and assessing fish stock -Monitoring and control of migrated/exotic species -Transboundary efforts for reduction of nutrients inputs	-Ministry of Environment, port Authority -Collaborations of the central governments by international agreements.

3.1.1. Adaptive management

"Adaptive management is an approach used to guide intervention in the face of uncertainty about the system. The main idea is that management actions are taken not only to manage, but also explicitly to learn about the processes governing the system.

This new information is then used to improve understanding of the system and hence to inform future management decisions. Monitoring is a key component. A plan for learning is fundamental – just to say 'oh that didn't work, let's try something else' is not adaptive management" (Shea 1998)[2].

No matter which adaptation option is chosen, this management approach should underpin the selection process in order for adaptation to be ultimately successful.

3.2. The basics of adaptation: Protect – Accommodate – Retreat

Climate change affects coastal areas through a combination of hazards. As such, adaptation to inundations originating from sea-level-rise and storm surges is based on three general strategies (Klein *et al.* 2001, Nicholls and Klein 2005)[1](Table 3.2):

1. Protect – reduce the likelihood of the hazard
2. Accommodate – reduce the impact of the hazard event
3. Retreat – reduce exposure by moving away from the source of the hazard.

Table 3.2. Three strategies (a combination of policy and technological options) for adaptation to SLR and storm surges [1]

Protect	Accommodate	Retreat
• Dikes, levees, floodwalls • Seawalls, bulkheads • Groynes • Floodgates and tidal barriers • Detached breakwaters • Periodic beach nourishment • Wetland restoration • Afforestation • Wooden walls • Stone walls	• Emergency planning • Insurance • Modification of buildings to cope with floods (strengthen and lift) • Improved drainage • Strict regulation in hazard zones • Modification of land use planning	• Increase or establish retreat zones • Relocate threatened buildings • Phase out or ban development in areas susceptible to flooding • Rolling easements, erosion control easements • Upland buffers

Similar policy and technological options are also adopted to cope with river floods caused by extreme rainfall events in the catchment upstream of a coastal area (Table 1). Possible adaptation measures include: increasing public awareness of possible floods, maintaining flood forecasting and warning systems, and reinstating floodplains through appropriate spatial planning.
Protection measures are also being studied to cope with the issue of seawater infiltration in coastal aquifers. This phenomenon is the first impact of sea-level-rise and affects the socioeconomic.

3.2.1 Accommodate, Retreat, and Revised Spatial Planning

The adaptation measures in Table 1 reduce coastal vulnerability by reducing the sensitivity of the
system (either natural or socioeconomic) to climatic events. Some of the options improve the resilience of the system by counteracting the effect of other external stressors that tend to increase the sensitivity to climate change. Albania and Georgia, for instance, should enforce *Accommodate* and *Retreat* measures based on rolling easements and *Revised Territorial Planning* (description) to tackle the unregulated (and at times illegal) coastal development of housing and tourism infrastructure which increases the risk of damages to material assets (i.e.
it increases the sensitivity of the socioeconomic system to sea-level-rise and storm surges).

Description:
Easements, setbacks, and zoning

- ***Erosion easements***

Erosion easements, defined as "legal agreements between a landowner and a land trust or the government agency that restricts development in erosion-prone areas," can be designed to:

• prohibit any type of development or control the size and/or density of structures,

• prevent shoreline hardening activities and/or specify what type of shoreline stabilization can be used, and

• prohibit the cutting of natural vegetation along the shoreline or restrict erosive activities.

In order to effectively protect property and coasts, easements can be coordinated at the regional scale so that all the properties over a large segment of coast have the same rules applied to them.

- ***Rolling easements***

These agreements are placed on a shoreline property to prevent the owner from holding back the sea. All other activities are allowed; there are no restrictions on building on the property. If the sea advances, the easement "rolls back" landwards. This is designed mainly to protect wetlands. Being aware that the property is susceptible to erosion, the owners have an incentive to build smaller mobile structures, easy to relocate. This, along with a prohibition on containing the sea, allows wetlands and coastal habitats to migrate naturally inland.

In the US, easements are voluntary, and land owners that choose to place an easement on their property receive a property tax break. This makes them more appealing than other regulatory approaches. On the other hand, they are
difficult to enforce and not as effective as setback lines and zoning overlays.

- ***State mandated setback regulations***

Construction setback regulations mandate that development must be a certain distance from the water. These, however, require good scientific data; they should be based on erosion data that is often difficult to get. Setback lines in South Carolina are re-assessed every eight to ten years. At times, establishing new lines means that the state
will need to compensate owners for their unbuildable property.

- ***Zoning and erosion overlays***

These strategies rely on state planning to limit development in erosion or flood prone areas, to minimize damages to property, and to eliminate the construction of defense structures. They can also contain rules for set-back lines and prevent clearing of native vegetation. However the government must have the capacity to regulate these measures; they require accurate data on areas at risk of erosion and flood, and may result in expropriation if development is already present"[3].

A reassessment of flood management will also be necessary in areas at risk of subsidence,particularly deltas and alluvial plains (e.g. Neretva in Croatia and Danube in Romania).

These areas are especially vulnerable to SLR and storm surges because they are usually densely populated, characterized by fast economic development, and at the same time they are the meeting point of saltwater and riverine freshwater (hence more exposed to floods).

In these areas flood management should be linked with spatial planning and integrated water resources management (example- Spatial planning in Jakarta). Adaptation to inundation from extreme rainfall events, sealevel-

rise, or a combination of the two needs to take into consideration the component of local subsidence. In deltaic areas this phenomenon can far outweigh climate change as the main cause of inundation, and it is often aggravated by the abstraction of groundwater for production activities and household use. The problem can be tackled by creating incentives for people and businesses to move to other areas of the coast, where their operations and water needs are deemed less likely to affect subsidence. Ideally, spatial planning and integrated water resources management should guide such changes, and should be applied at the watershed scale to effectively protect material assets while at the same time regulating the quality and quantity of water reaching the coastal zones.

- **Example: *Spatial planning in Jakarta*** [4]

"Jakarta, capital of Indonesia, experienced several floods of the downtown area in 2007, with two major inundations in January and November. Analysis of hydrological, geological, and sea-level-rise data shows that subsidence is the principal cause (Figure 3.1)[4].

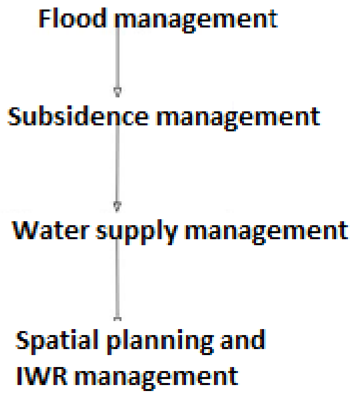

Figure 3.1. Diagram of spatial planning [4]

The city is sinking mainly due to water abstraction from underground. The sinking rate is much higher than any increase in sea-level-rise (from 2007 to 2025 predicted increase in sea-level-rise is 4 to 6 cm and predicted subsidence is 40 to 60 cm). Subsidence is also enhancing the sensitivity to storm surges and periods of high tides. While immediate measures like dredging of canals and barriers are necessary, the long time solution consists in scaling up the intervention, moving from flood management to water resources management to urban and territory planning. In order to control the subsidence process, water abstraction must be regulated. One solution proposed to the city by external advisors and experts from the Dutch Institute for Delta Applied Research is to reduce water abstraction in the most sensitive areas of the city by modifying spatial planning and pushing businesses and residents out of these areas, thereby shifting the demand for water away from the areas at greatest risk of flooding.'[4]

Spatial planning at the watershed scale has been adopted in the Netherlands as a critical strategy

to cope with the threats of climate change and increased river flow (example –description Living with floods in the Netherlands). The strategy, known as "living with floods" or "room for the river", hinges on general revision of zoning and on setting aside areas to be flooded, in case of inundations due to extreme precipitation and river overtopping. The advantage of such a policy is that floods are controlled by being directed to areas designed to withstand such events. This is accomplished either by leaving these lands to nature, or by strictly limiting the type of allowed activities and enforcing precise building codes.

While this strategy is, in the long-term, the most sound from a socioeconomic and environmental point of view, it must be recognized that it requires vast investments in the short-term and the advantages can be seen only over long periods. It follows that this strategy has economic sense mainly for areas where exposure and sensitivity are very high, and where the population affected and the value of natural and material assets are very large.

- **Example: *Living with floods in the Netherlands***

"The government of the Netherlands, which has expertise in flood management, has integrated protective measures (dykes and barriers) with the use of "resilience strategies." These are based on the definition of risk associated with flooding (either from rivers, sea, or a combination of the two) as determined by the likelihood of a flood multiplied by the damage caused by it. Building higher dykes (strategy of resistance) is a very costly strategy when factoring the costs associated with a possible failure in protection (Vis *et al.* 2003)[5]. The sense of security provided by higher and stronger dykes promotes more investments in the vicinity of the defense structures. This, in combination with the rise in sea level outside the dykes makes a possible breach and flooding event all the more catastrophic. The strategy of resilience is based on reducing the risk of damages (living with floods) by trying to minimize the likelihood of a flood event and by allowing only certain areas to be flooded. The advantage is that the inundation is controlled, by being directed in zones that have been prepared for these occurrences through spatial planning and building codes"[5].

3.2.2 Adaptation for the fishery sector

In the ECA basins, in particular in the Baltic, Black, and Caspian Seas, rising sea temperatures in combination with modifications in run-off due to changes in precipitation may impact the productivity of fisheries. The best adaptation option is to tackle those stresses other than climate change that increase the sensitivity of fisheries to climate change by negatively affecting fish stocks; overfishing, spread of exotic species, organic and inorganic pollutants leading to eutrophication are the factors that in the last decades have contributed to a drastic reduction in productivity of the fishery sector in these three basins. Given the nature of ECA sea basins, these results can be obtained only through a concerted international effort including the countries that are part of the drainage basins. In this respect the GEF transboundary project for the Danube has already obtained results in reducing the input of nutrients in the Black Sea, and the GEF Baltic Sea regional project is proceeding toward the realization of an integrated management of the basin.

3.2.3 Issues with the development of adaptation options

A strategic coastal management for climate change should be based on the following:
1. Development in coastal zones and in flood-risk zones needs to take into account climate change impacts, and as a result requires long-term planning in:
a. Development objectives
b. Transports and utilities
c. Energy sector
d. General land use regulations and spatial planning
2. Regional and national scale policies must be transferred down to the local level, empowering local authorities and giving them mandate for the implementation of long-term practical adaptation measures.
3. The strategies need to take into consideration the full set of options: Protect / Accommodate / Retreat.
Inclusion of options other than *Protect* will require difficult decisions and create some tension between stakeholders. In this respect it is necessary to recognize the local stakeholders as:
1. Directly affected categories: land and home owners, fishermen, etc.
2. Local and central government decision makers for coastal management (usually they also deal with development control and land use planning)
3. Public and private organizations (e.g. nature conservation and others).
The first group is likely to resist major planning changes that may affect their possessions. In this case information and education on the short-term and long-term impacts is critical, but it can be implemented only if there is a concerted effort from national and local authorities.
The implementation of successful measures will require “public inclusion, negotiation, integrate planning and implementation”, along with necessary legislative changes that will need to underpin modification in spatial planning and land use, and allow for “compensation and acquisition of property in erosion and flood risk zones” (Few *et al.* 2004). Such a process is difficult and lengthy, which

increases general vulnerability and makes the climate change threat even more challenging.

3.3. Adaptive capacity

3.3.1 Adaptive capacity in the context of coastal areas

Klein *et al*. (2001)[1] define adaptation to climate change in coastal areas as a policy process organized in a series of steps involving consultation, decisions, and technical applications (Figure 3.2)[1]:

1. Information – awareness (includes data gathering for vulnerability assessment)
2. Planning design
3. Implementation
4. Monitoring and evaluation.

This framework reminds policy makers and scientists that adaptation is part of a broader policy process, and identifies obstacles and opportunities (i.e. costs and benefits) for adaptation.

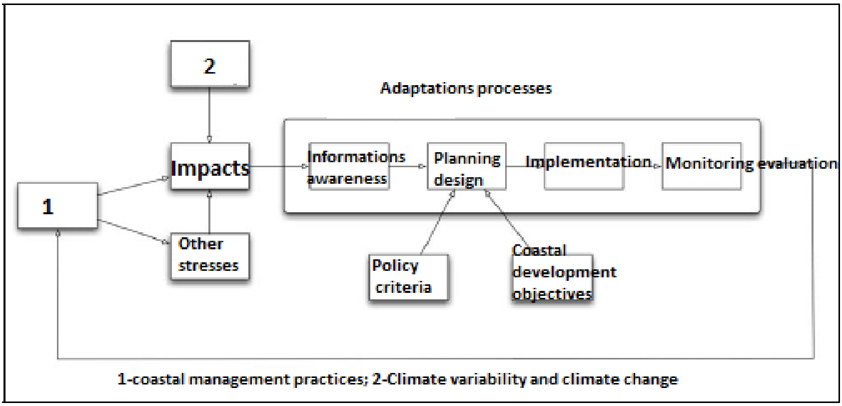

Figure 3.2. Framework for planned adaptation [1]

The adaptation process starts with raising awareness of policy makers and the general public about the possible impacts of climate change, and gathering knowledge on the vulnerability of the coastal areas. The planning and choice of adaptation measures is influenced both by policy criteria (cost effectiveness, environmental sustainability, cultural compatibility, and social acceptability) and by coastal development objectives (Klein *et al.* 2001). Once the selected measures are implemented their monitoring and evaluation refines coastal management.

(central government, local authorities, private enterprises, and the public-at-large) to drive and carry on the different phases of the adaptation process at a pace that is adequate to the rate of climatic changes. It is this capacity, rather than the mere availability of adaptation measures, that determines the vulnerability to climate change (in combination with exposure and sensitivity).

3.3.2. Awareness and education on coastal climate change is not adequate

Awareness and knowledge about the climate threat and about possible solutions is the first step in the adaptation process, and the basic condition for the development of an adequate adaptive capacity. In order to plan, implement, and respond promptly to adaptation measures, awareness must be equally rooted in experts of the socioeconomic and scientific disciplines, in government agencies, and in the public-at-large.

The main aspects of awareness are:

1. Awareness of the different components of climatic exposure in coastal areas
2. Awareness of how the exposures affect coastal areas, the modifications induced and how these areas respond (naturally, e.g. coastal dynamics)
3. Knowledge of how climatic stresses and non-climatic stresses interact and compound their effects.

According to Tol *et al.* (2008), in the Black Sea and Mediterranean basin, awareness is limited to a few academics, and no knowledge has efficiently permeated the institutional levels in charge of spatial planning and coastal management. Bulgaria, Romania, Ukraine, Turkey, and Croatia (but also Italy, Spain, and others) have low awareness of the implications of climatic change on coastal areas, and currently have no plan for adaptation (example-). In the Baltic Sea, Estonia and Lithuania have low climate change awareness, and there vulnerability refers mainly to coastal ecosystems, while their socioeconomic systems have low overall sensitivity. Poland, on the other hand, has started a national coastal plan that includes analysis of SLR (Tol *et al.* 2008).

In general, the level of education and interest in the effects of climate change is low. The reasons for this are varied, but they are generally the result of current social, economic, and political challenges faced by the countries in the aforementioned basins, and their current focus on short-term issues.

Example: Adaptive capacity in Turkey

The main impediment to the development of adaptive capacity in Turkey is the very low awareness of coastal dynamics and climatic impacts, both in the institutions and among the public. Despite the plan by the Ministry of Environment to create a Department for Environmental Impact Assessment, no governmental body is presently dealing with the future consequences of sea-level-rise and other climatic events on coastal areas (Karaca and Nicholls 2008)[6]. Both a cause and a result of this condition is the lack of specific data and of appropriate methodologies to analyze impacts. However, part of the problem is also in the coastal protection law, which defines sea level as unchanging. A long-term coastal management plan is missing, and coastal issues are not a national priority unless they entail investments and infrastructures for the tourism industry. A result of this situation is the lack of consideration for increasing sea-level-rise and other environmental changes during the recent expansion of coastal infrastructure, both ports and protection works (Karaca and Nicholls 2008)[6], [7], [8], [9].

3.4. *Lab 3.* Case study: the factors and the constraints affecting adaptive capacity.

1. The way forward – Finding and analyzing the factors affecting adaptive capacity in ECA

Awareness and education are the *conditio sine qua non* for effective adaptation. The question remains, however, of what is the status of the other elements/dimensions of adaptive capacity if we assume that adequate awareness is attained.
Identifying the dimensions of adaptive capacity is a complex task. It is particularly so for coastal areas because of their geographical and multi-sectored nature. A first analysis of adaptive capacity can be obtained by using country-level indicators of resource endowments, but these seldom capture all dimensions, including effective strengths and weaknesses. For instance, the weight of institutions and social networks in determining the level of adaptive capacity may be very different from place to place (Brooks *et al.* 2005).
To further complicate the picture, coastal areas are often simultaneously under control of regional, national and international authorities.

1.1. General questions –Indicators for adaptive capacity

Presently, some questions can be posed to identify the elements of adaptive capacity. Given that these elements must refer to the actors mentioned previously (central government, local authorities, private sector, public-at-large), some questions will address general dimensions (education, governance), while others will be specific for coastal areas and their impacts. The questions, taken from Tol *et al.* (2008)[10], Yohe and Tol (2002)[11], and Adger *et al.* (2007)[12], are outlined below:

1. Awareness and education on the consequences of SLR and possible adaptations

a. Is the knowledge available both to institutions and the public? I.e. are the relevant
people informed?

b. Are skilled and trained personnel available?

2. Technological options entailing knowledge in engineering, natural sciences, planning, etc., and a good level of communication and exchange between levels of governance and between neighboring countries

a. Does the society have the technical means to act?

3. How is the governance quality at central, regional, and local levels?

4. Does the central government have the ability to modify legal framework and implement changes at the local scale, whether it is for Integrated Coastal Zone Management or planning?

a. What is the quality of knowledge dissemination and communication between different institutional levels? This indicates that the society has the structure and network to facilitate action on climate change.

5. Resources and their distribution

a. Are there economic means to be able to implement adaptation measures and to do it in a timely fashion?

6. What is the state of human capital, including education?

7. What is the state of social capital, including property rights (intimately linked with quality of governance)?

8. How accessible are risk spreading mechanisms (i.e. insurance, etc.)?

9. What is the state of social infrastructures and equity?

It is important to clarify a subtle but important aspect of adaptive capacity. In order for adaptive capacity to be adequate, each element must be present to a “satisfactory” level. In other words, no element can fully substitute for another. Better education is not a substitute for economic means, and technological options is not a substitute for governance (Tol *et al.* 2008).

1.2. Insight into the current state of adaptive capacity in ECA

Taking as an example the water sector in ECA sub-regions, Table 3.3 provides insight into a range of conditions that may currently help or hinder the development of adaptive capacity in local authorities and central government agencies. The table focuses on those aspects of water management that also affect adaptation strategies in coastal areas.

Table 3.3. Issues and status of adaptive capacity of water sectors

Sub-Region	Institutional framework	
	Factors favoring adaptive capacity (+)	Factors hampering adaptive capacity (-)
Central Europe – Baltic Sea – Slovenia	• Baltic: 15 years of cooperation program to reduce pollution loads from municipal and industrial sources • The GEF Baltic Sea Regional Project is addressing safe agricultural practices and coastal zone management.	• Poor cooperation between administrative bodies – must modify legislation to specify responsibilities and functions • Improve capacity at various levels. • Lack of funds recently has hampered the maintenance of flood protection structures.
Southeastern Europe	• Romania and Bulgaria legal water frameworks already in line with EU • Efforts to adapt laws and institutions to the EU water Framework Directive (focus on river basin management)	• Poor effectiveness of managing institutions and legal frameworks
Turkey and Caucasus	• Water institutions are technically strong.	• Water institutions are managerially weak. • Lack of data on the water sector • There exist complex legal issues with water rights, a lack of statutory priorities in the current legal framework – many entities share the responsibility for development, management, and protection of water resources. • Inefficient and sometimes obsolete institutional framework – lack of coordination and several organizations performing the same duties • Need to formulate comprehensive strategies for WRM[22] and bring in different stakeholders
Russian Federation	• Long tradition of integrated river basin management, monitoring of hydrology and weather needs to be fixed after the collapse of the USSR.	• Unsatisfactory safety of dams and other hydraulic infrastructures • Institutional and legal frameworks for sustainable use are in place but implementation is very poor – all the structures need to be potentiated.
Moldova, Belarus, Ukraine	• *Lower Danube Green Corridor* to protect sensitive aquatic ecosystems of Moldova, Ukraine, Bulgaria, Romania • Permit system for water withdrawal – payments for water use (regulation in case of droughts)	• Legal, regulatory, and administrative weaknesses • Need to strengthen institutional capacity in WRM • Poor coordination between various agencies • Lack of a sectored planning approach (rather than at the river basin scale) • Flood control is ineffective and transfers the impacts from upland to lowlands.
Central Asia	• Strong water institutions at the national level	• Water use efficiency is very low (70% of water taken for irrigation is wasted). • Decaying water infrastructure • The five riparian countries of the Caspian Sea dispute the legal status of the sea (this hinders effective tackling of pollution, fisheries, and biodiversity issues).

For what concerns issues of transboundary nature, like the impact of climate change on fisheries, adaptive capacity is adequate in the Baltic Sea, mainly due to the history of collaboration between countries and to the current GEF regional project addressing coastal zone management.
In the Black Sea, capacity is low. Fisheries have collapsed in the last decades probably due to overfishing, pollution, and the spread of the exotic species *Mnemiopsis leidyi*. However, the lack of a uniformly accepted method to monitor fish stocks and the ensuing poor data availability means that there is no single accepted scientific result on the

causes of the collapse, which makes it harder to frame a strategy of adaptation. The GEF has worked at developing a convention for the management of fisheries in the Black Sea, but the progress between parties halted when Bulgaria and Romania joined the EU. The move subjected the two countries to the Common fishery policy, but Brussels does not have good knowledge of the status of the fisheries in the Black Sea, and at present the situation is stalled (Ivan Zadavsky GEF Staff, personal communication).

In the Black Sea, the only basin currently having good transboundary management and collaboration between countries is the Danube watershed. The International Commission for the Protection of the Danube River (ICPDR) could therefore have the capacity to deal with the future climate change threats. In terms of control of pollution (as an adaptation strategy), the Commission for the Protection of the Black Sea Against Pollution (2007) is presently struggling, and has limited capacity to monitor and intervene (Ivan Zadavsky GEF Staff, personal communication).

In the Caspian Sea, the level of management and collaboration is represented mainly by the Framework Convention for the Caspian marine environment. 2006 marked a Conference of affiliated parties. Collaboration is well established, but there is concern about future successful implementation of the 4 protocols under preparation:

(1) EIA transboundary,
(2) Biodiversity,
(3) land base sources of pollution,
(4) Mutual aid in case of oil spills from shipping.

2 Constraints to developing adaptive capacity

In order to optimize adaptation to climate change in coastal areas we need to work on the spatial and temporal scales of action:

A. Spatial Scale: a water basin approach is needed to tackle sustainably all the various factors affecting coasts, originated by climate change or acting in synergy with it.

However, one needs to be concerned about the mismatch between the broad geographical scale (region, watershed, basin, etc.) at which the adaptation strategy is planned, and the local spatial scale at which decision-making for coastal management must be translated into action (Few *et al.* 2004).

B. Temporal scale: the time horizon of local coastal planning is often very short and unsuitable to include considerations of climate change and adaptation strategies.

2.1. The spatial scale issue

Strategic coastal management planning is developed principally at the regional and national scale. Policies then need to be transmitted down to local authorities, along with a clear mandate empowering them to adopt a long-term planning strategy that takes climate change into consideration. For this transition to happen, institutional capacity needs to be built both at the national and local scales. This is one of the main challenges that has been hampering the successful implementation of national and supra-national strategies, for instance integrated

2.2. The temporal scale issue

At the local government level there are several constraints to strategic long-term planning:
1. Resources constraints – financial and human
2. Limited mandate of the local planning departments
3. Lack of detailed data on future long-term exposure of the area
4. Technical ability to interpret these projections correctly.

The knowledge and information limitation (number 3 above) originates from the uncertainty surrounding the local magnitude of climate change exposure, and the local sensitivity of the coasts to climatic hazards. The best solution is to first identify all the currently known sources of coastal vulnerability, and then design measures to tackle these issues within an adaptive management framework. In order to do this, decision support tools can be useful, as they guide decision-making in the face of uncertainty.
At the same time, it is necessary to develop a system of scenario projections at the local scale, so that, starting with particularly sensitive areas24, one knows what the likely exposure will be and how sensitive the “natural protection” (geological features of the coast) is. As noted before, none of this can be achieved without general awareness of the threat of climate change on behalf of planners, decision makers, coastal managers, and the general public (Klein *et al.* 2001)[1].

2.3. The uncertainty issue

General uncertainty and the other limitations represent a disincentive for local authorities to embrace long-term planning, and instead reinforce the allocation of resources toward short-term matters.
Uncertainty also complicates the dialogue between decision-makers, private stakeholders, property owners, and the public-at-large. This is

especially true when the long-term adaptation measures entail losses of property. In a related matter, it should be kept in mind that in many instances the general public is averse to long-term thinking, and may be unable to put in perspective the proposed solutions. Finally, the “political momentum” toward development that runs contrary to the call for long-term planning and modification of coastal management strategy should not be underestimated.

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Chapter 4

GENERAL ELEMENTS REGARDING THE WAVE PHENOMENON

4.1. Introduction

The generation of energy from waves has, due to the high density of water, a high degree of concentration; the yields of transformation of raw (mechanical) energy into electricity are higher than in the case of wind and solar energy. The major disadvantages are those related to the corrosion of sea water and the marine atmosphere, which lead to the use of expensive materials. Shell deposits, as well as solid materials brought by the wave (sand, algae, etc.), lead to additional maintenance costs [1]. Today, many countries are trying to build, and some have built, marine hydropower plants in the specific conditions of the waves in the seas and oceans accessible to them.

4.1.1. Brief history of physical - mathematical studies about waves

The non-permanent phenomenon of free surface movement represented by waves has been the subject of theoretical works since the last century.

The problems of the waves affected a considerable number of mathematicians, apparently beginning with Lagrange and continuing with Cauchy and Poisson in France. Later, the British school of mathematicians-physicists made notable contributions through Airy, Stokes, Kevin, Rayleigh and Lamb.

In the latter part of the 19th century, the French school returned through Saint Vénant and Boussinesq, and later through Poincaré. His studies were developed in Russia by Lyapunov. One of the most complete studies of applied mathematics in the field of finite amplitude waves belongs to A. Nekasov (1921 and 1951, The Exact Theory of Stationary Waves on the Surface of a Heavy Fluid, USSR Academy, Moscow).

Separate studies with similar results had T. Levi - Civita in 1925 in the rigorous determination of permanent waves of finite amplitude (Mathematical Annals, vol. 93, Germany).

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4.2. Wave classification

A first classification criterion based on the factor that generates the wave has already been mentioned. So we have:
- waves produced by the movement of solid bodies in water (for example, ships);
- seismic waves;
- tidal waves.

Another classification criterion is that of the duration of the action of the disturbing force:
- maintained waves, at which the force that generated the wave continues to act;
- free waves, at which the disturbing force has stopped, the undulating movement continuing due to the inertial forces.

According to the depth of the water in which the wave propagates:
- deep water waves, in which the geometry and movement of the waves are not influenced by the presence of the water bottom;
- shallow water waves, in which the trajectory of the water particles is influenced by the friction with the bottom of the aquarium.

According to the geometric dimensions of the wave:
- short waves, in which the length of the ratio between the wavelength and the wave height is $\lambda / h \leq 40$, and the ratio between the wavelength and the water depth, $\lambda / H \leq 2$;
- long waves, at which $\lambda / h > 40$, and $2 < \lambda / H < 25$.

By frequency of wave crests:
- solitary waves, in the form of a single traveling ridge, are generally the singular waves caused by earthquakes;
- periodic waves, are the classic waves produced by the wind.

4.3. Practical class: The genesis of waves

The waves have different origins. Next we will refer to the waves caused by the wind, but it must be said that there are other possibilities of waves: the first is the movement of solid bodies on the surface of the water, the second the sudden movements of the earth's crust, which can generate so-called single waves. they have enormous energies and heights of up to 30 m. Small amplitude waves can also form due to the tides.

Wave energy is based on solar energy. It is absorbed by water surfaces, causing evaporation. The uneven distribution of evaporation

on a planetary scale, given the existence of land, leads to uneven density distributions of the lower atmosphere (difference in barrel potential). These differences are equalized by the movement of air from one area to another, in the form of wind.
In turn, winds act on water surfaces, transferring mechanical energy directly to them, producing waves. The air flow in the boundary layer drives the surface layer of water, proportional to its intensity. At a certain speed, the local turbulences produce the unevenness of the water surface, accentuating the energy transfer, and by the permanence of the movement and by the increase of the wind speed the phenomenon is amplified. Finally, the transfer of energy from the wind to the surface of the water translates into the appearance of waves, undulating movements, with an extremely complex dynamics, both as a distribution in a space field and as an evolution in the direction of propagation.
Wind energy is transformed into hydraulic energy, which occurs in three aspects:
- the potential energy of the different liquid particles that are raised or lowered in relation to the initial equilibrium level;
- the kinetic energy of the same particles in orbital motion in which they are entrained;
- capillary energy due to the elongation of the liquid surface under the effect of corrugations.
This form of energy has a much lower weight than the other two, practically not being taken into account.
Some authors also give minimum values of wind speed for producing waves. A minimum speed of 0.695 m / s is required for ″priming ″ the waves, and a speed of 1.0 ÷ 1.5 m / s is sufficient for them to increase [2].

4.4. Lab 4: <u>The geometrical elements of the waves</u>

At a sufficiently large distance from the place where they were generated, the waves have a trochoidal shape: the curve is described by a point P inside a circle of radius R, which rolls on a line Δ. From Figure 4.1 [1] it is observed that between the radius R and the wavelength λ there is the relation R = λ /2 π. It is also observed that the distance from the point P describing the trochoid to the center of the circle is half the height of the wave OP = h / 2 (Figure 4.1) [1]:

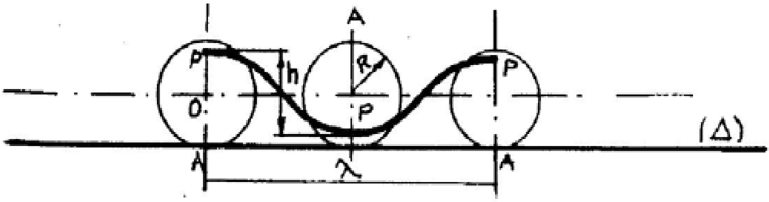

Figure 4.1. The shape of wave [1]

There are defined below:
- the direction of propagation is the direction in which the wave is advancing;
- the back of the wave is the portion located above the resting level of the chid, having at the highest part the crest of the wave;
- the wave gap is represented by its lower part located below the level of water rest; the lower part of the surface is called the sole of the wave.

Next we define the geometric elements characteristic of the wave:
- the height of the wave, h, represents the vertical distance between the ridge and the sole the wave (Figure 4.2) [1];
- the wavelength, λ, represents the horizontal distance between the ridges a two successive waves;

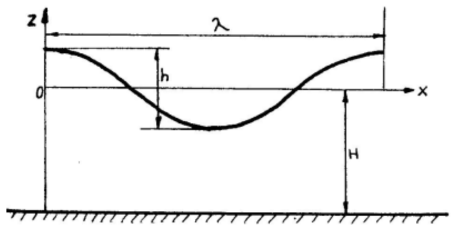

Figure 4.2. The elements of wave [1]

- the water depth, H, represents the vertical distance between the static level of water and the bottom of the aquarium.

In the following can be defined:
- the speed, c, is the speed of wave propagation (Figure 4.3)[1];
- the period of the wave, T, is the time in which the wave of the wave travels a distance equal to the wavelength; obvious $T = \lambda / c$;
- the frequency of the waves, f, represents the inverse of the period $f = 1 / T$;

- the wind fetch, F_w, represents the required horizontal length of the one of the wind on the surface of the water, so that the wave develops completely;
- the duration of the wind action, T_w, represents the time in which the wind acted- and transfers its energy to the surface of the water.

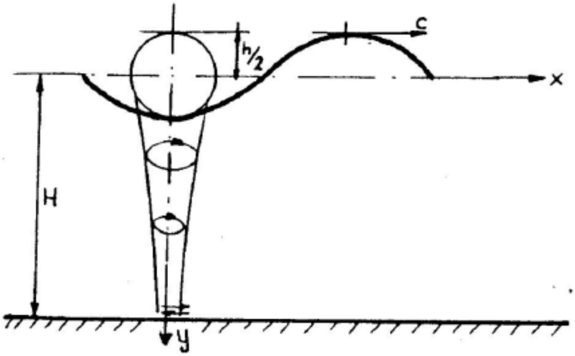

Figure 4.3. The cinematics of wave

Table 4.1. Maximum wave elements with 1% assurance depending on wind speed W [3]

Wind		The maximum height h with the assurance of 1% and the values λ and T corresponding to it		
Intensity [grade]	Speed W [m/s]	h [m]	λ [m]	T [s]
4	6	1,4	22	3,8
5	9	2,9	50	5,7
6	11	3,9	76	7,0
7	14	6,0	123	8,9
8	17	8,3	181	10,8
9	20	10,9	250	12,7
10	23	14,0	330	14,6
11	27	18,2	455	17,1
12	30	21,9	564	19,0

To see the order of magnitude of the defined elements, in Table 4.1, the elements of the maximum waves with 1% assurance are given (only 1 in

100 waves have elements larger than those given in Table 4.1), depending on the wind speed W [3].

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Chapter 5

THEORETICAL TREATMENT OF THE WAVE PHENOMENON

5.1. Mathematical treatment of the wave phenomenon in the hypothesis of the perfectly incompressible liquid

The movement of the waves is a non-permanent movement, but flat, periodic and potential. The hypothesis adopted, of ideal fluid (non-viscous) is not far from reality because the speeds are low and the fluid is heavy and incompressible.

5.1.1. Obtaining the trajectory of the movement

With the axis system chosen as in Figure 5.1 [1], We will write the equations of motion:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{1}{\rho}\frac{\partial p}{\partial x} = 0$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + \frac{1}{\rho}\frac{\partial p}{\partial y} = g, \quad (5.1)$$

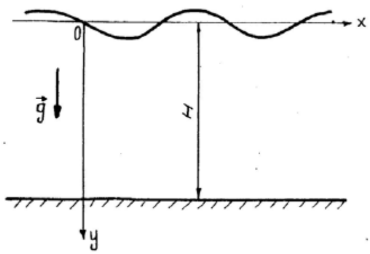


Figure 5.1. Axis system for wave motion equations

Continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0. \tag{5.2}$$

Will be now introduce the potential function of speeds:

$$\vec{v}=grad\,\varphi=\vec{\nabla}\,\varphi=\vec{i}\,\frac{\partial\varphi}{\partial x}+\vec{j}\,\frac{\partial\varphi}{\partial v}=\vec{i}\cdot u+\vec{j}\cdot v, \tag{5.3}$$

Where $u=\dfrac{\partial\varphi}{\partial x};\quad v=\dfrac{\partial\varphi}{\partial y}.$

We use the indirect method to solve. We consider φ the form:

$$\varphi(x,y,t)=f(y)\cdot g(x,t)=f(y)\cdot\cos(kx-\omega t), \tag{5.4}$$

Given that the phenomenon is periodic.
The continuity equation (5.2) written after φ becomes:

$$\Delta\varphi=0;$$

$$\frac{\partial^2\varphi}{\partial x^2}+\frac{\partial^2\varphi}{\partial y^2}=0, \tag{5.5}$$

Meaning

$$-k^2\cdot f(y)\cdot\cos(kx-\omega t)+\frac{\partial^2 f}{\partial y^2}\cdot\cos(kx-\omega t)=0,$$

Or

$$\frac{\partial^2 f(y)}{\partial y^2}-k^2\cdot f(y)=0, \tag{5.6}$$

which is a homogeneous Euler equation of order II with constant coefficients and which admits solutions of form:

$$f(y)=C\cdot e^{r\,y}. \tag{5.7}$$

By introducing (5.7) in equation (5.6) will obtain:

$$C\cdot r^2\cdot e^{ry}-k^2\cdot C\cdot e^{ry}=0; \tag{5.8}$$

$$r^2 - k^2 = 0,$$

with solutions:

$$r = \pm k. \tag{5.9}$$

Thus, we obtain the general solution of equation (6) of the form:

$$f(y) = A \cdot e^{ky} + B \cdot e^{-ky}, \tag{5.10}$$

and the potential function becomes:

$$\varphi(x, y, t) = \left(A \cdot e^{ky} + B \cdot e^{-ky}\right) \cdot \cos(kx - \omega t). \tag{5.11}$$

To determine the constants A and B we set the conditions to the limit:
- on the bottom of the water

$$y = H;$$
$$v = 0;$$
$$\frac{\partial \varphi}{\partial y} = k\left(A \cdot e^{ky} - B^{-ky}\right) \cdot \cos(kx - \omega t) = 0 \, , \tag{5.12}$$

meaning

$$Ae^{kH} = Be^{-kH} = -\frac{C}{2}$$

$$A = -\frac{C}{2} \cdot e^{-kH},$$

$$B = -\frac{C}{2} \cdot e^{kH}. \tag{5.13}$$

Entering in (5.11)

$$\varphi = -C \cdot \frac{e^{k(y-H)} + e^{-k(y-H)}}{2} \cdot \cos(kx - \omega t) = C \cdot ch \cdot k(H - y) \cdot \cos(kx - \omega t). \tag{5. 14}$$

Below we express the speed components on the two axes:

$$u=\frac{\partial\varphi}{\partial x}=Ck\cdot ch\;k(H-y)\;\sin(kx-\omega t)=\frac{dx}{dt},$$

$$v=\frac{\partial\varphi}{\partial y}=Ck\cdot\;sh\,k(H-y)\cdot\cos(kx-\omega t)=\frac{dy}{dt}.$$

(5.15)

Further, the parametric equations of motion can be obtained by eliminating by integration the time t from the equations (5.15):

$$x=d_1+\frac{Ck}{\omega}\cdot ch\cdot k(H-y)\cdot\cos(kx-\omega t),$$

$$y=d_2-\frac{Ck}{\omega}\cdot sh\,k(H-y)\sin(kx-\omega t),$$

(5.16)

and bearing in mind that:

$$\sin^2(kx-\omega t)+\cos^2(kx-\omega t)=1,$$

can obtain

$$\frac{(x-d_1)^2}{\frac{C^2k^2}{\omega^2}ch^2\,k(H-y)}+\frac{(y-d_2)^2}{\frac{C^2k^2}{\omega^2}sh^2\,k(H-y)}=1.$$

(5.17)

Considering with good approximation that y = ct, we will note the terms from the denominator:

$$\frac{C^2k^2}{\omega^2}ch^2\,k(H-y)=a^2;$$

$$\frac{C^2k^2}{\omega^2}sh^2\,k(H-y)=b^2,$$

and so equation (5.17) is the equation of an ellipse:

$$\frac{(x-d_1)^2}{a^2}+\frac{(y-d_2)^2}{b^2}=1. \qquad (5.18)$$

5.1.2. Obtaining the trajectory of the movement

So the trajectories of water particles in the motion of waves are approximately elliptical of semiaxes a and b, as follows:

a) the surface (y = 0):

$$a=\frac{Ck}{\omega}\,ch\;kH; \qquad b=\frac{Ck}{\omega}\,sh\,kH,$$

which for H large enough, according to the variation of the hyperbolic functions in Figure 5.2 [1], leads to:

a = *b*

therefore, on the surface the trajectories are circles;

b) at the bottom of the basin (y = H): $a=\frac{Ck}{\omega}, \quad b=0.$

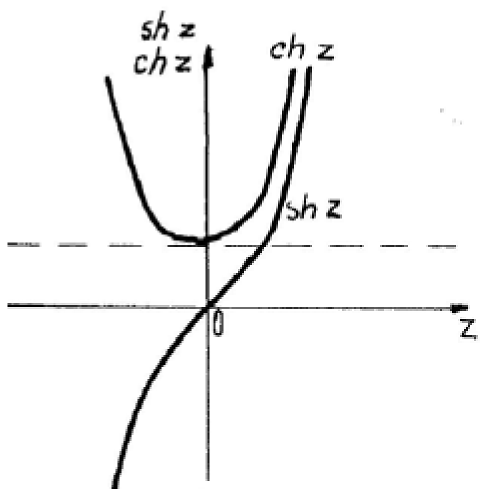


Figure 5.2. Surface wave trajectories [1]

Therefore, the trajectories of particles are ellipses that decrease exponentially with increasing depth; at the same time (Figure 5.3)[1], they flatten at the bottom, transforming into an alternative rectilinear movement, without vertical component:

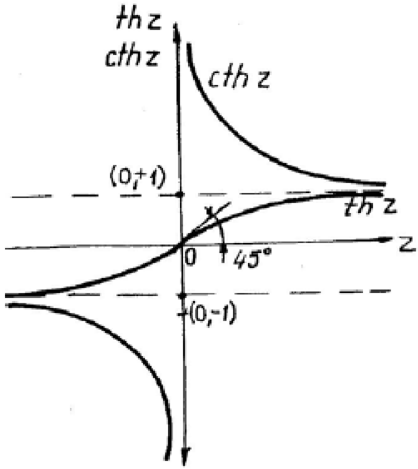


Figure 5.3. Variation of wave trajectories with depth [1]

5.2. Calculation of wave parameters: pulsation, wavelength, propagation speed

Denote by η the function that expresses the variation of the y ordinate on the free surface [1]:

$$\eta = y /_{\text{free surface}} \tag{5.19}$$

Bernoulli's equation on the free surface:

$$\frac{p_o}{\rho} + U + \frac{v^2}{2} + \frac{\partial \varphi}{\partial t} = C(t). \tag{5.20}$$

We neglect the terms $\frac{p_o}{\rho}$ and $\frac{v^2}{2}$ because the kinetic energy is small compared to the gravitational forces and the variation of the potential in time.

Suppose that the value of the constant C (t) is zero at a time t_o:

$$C(t)\Big|_{t=t_o} = 0,$$

we write the potential of mass forces as:

$$U = g \cdot \eta \,. \tag{5.21}$$

Under these conditions Bernoulli's equation becomes:

$$\left[g\eta + \frac{\partial \varphi}{\partial t} \right]_{t=t_o} = 0,$$

So

$$\eta = -\frac{1}{g}\left[\frac{\partial \varphi}{\partial t} \right]_{\substack{t=t_o \\ y=0}} \tag{5.22}$$

and taking into account φ expression

$$\eta = -\frac{C\omega}{g}\, ch\, kH \cos\left(kx - \omega t\right). \tag{5.23}$$

Next we write in two ways the vertical component of speed, v:

$$v\Big|_{y\approx\eta} = \frac{\partial \varphi}{\partial y}\Big|_{y\approx 0} = Ck\, sh\, kH \cos\left(kx - \omega t\right), \tag{5.24}$$

$$v\Big|_{y=\eta} = \frac{\partial \eta}{\partial t} = \frac{C\omega^2}{g}\, ch\, kH \cos\left(kx - \omega t\right). \tag{5.24'}$$

By equalizing the two expressions, we obtain after simplifications the phenomenal pulsation periodic table:

$$\omega = \sqrt{k \cdot g \cdot th\, kH}\,. \tag{5.25}$$

The ordinate y in (5.16) becomes on the free surface:

$$y = d_2 - \frac{Ck}{\omega}\, sh\, kH \sin(kx - \omega t).$$ (5..26)

If will set the conditions:

$$y\Big|_{t=0} = y\Big|_{t=T}$$

will get the wavelength

$$\lambda = \frac{2\pi}{k},$$ (5. 27)

and period

$$T = \frac{2\pi}{\omega}.$$ (5.28)

Wave propagation speed, or speed celerity:

$$c = \frac{\lambda}{T} = \frac{\omega}{k} = \sqrt{\frac{g}{k} tg\, kH} = \sqrt{\frac{g\lambda}{2\pi} th \frac{2\pi\, H}{\lambda}}\ .$$ (5.29)

Therefore, speed celerity:

$$c = c(\lambda, H).$$

In the case of shallow waters, λ> H, the angle made by the th z curve is 45 °, so:

$$th\, z \to 1, \quad th \frac{2\pi\, H}{\lambda} \to 1,$$

and speed celerity:

$$c = \sqrt{\frac{g\lambda}{2\pi}}$$

it is no longer influenced by the presence of the bottom of the basin. The variation c = c (λ, H) is shown in value in Figure 5.4, based on the relation (5.29).

Based on the relations deduced between the wave parameters, completed with experimental measurements, Titov proposes the diagram presented in Figure 5.4 which represents a synthesis of the characteristics of real offshore waves depending on the wind speed.

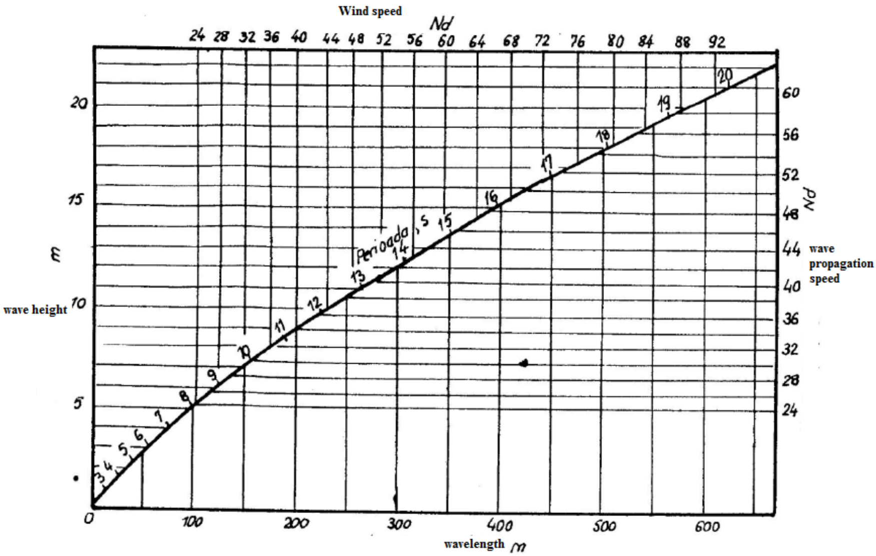


Figure 5.4. Titov's diagram for the characteristics of real offshore waves as a function of wind speed [1]

Neumann presents the variation of the main parameters of the waves: speed c, wavelength λ, wave height h, wave period T, depending on the wind speed W in two cases: maintained waves and fully developed waves, also called blasphemy waves.
Remember that blasphemous waves are those waves in which, the time and length of action of the wind on the surface of the water being large enough, cause speeds of movement of the wave c greater than the speed of the wind that generated them: in this case, the waves do not they are also considered maintained but free (waves at which the force of the wind has ceased, they continue to propagate due to the forces of inertia). This dependency is shown in Table 5.1 [2]:

Table 5.1. Comparative analysis of wind-maintained waves **-** fully developed waves

W	wind maintained waves				fully developed waves			
[m/s]	*c* [m/s]	λ [m]	*h* [m]	τ [s]	*c* [m/s]	λ [m]	*h* [m]	τ [s]
2	0,85	0,46	0,05	0,54	2,74	4,81	0,11	1,76
3	1,46	1,36	0,13	0,93	4,11	10,80	0,24	2,64
4	2,12	2,88	0,26	1,36	5,48	19,20	0,43	3,51
5	2,84	5,18	0,43	1,82	6,84	30,00	0,67	4,39
6	3,60	8,31	0,66	2,31	8,21	43,20	0,96	5,25
7	4,41	12,40	0,93	2,83	9,60	59,10	1,32	6,15
8	5,25	17,60	1,27	3,36	11,00	79,80	1,71	7,03
9	6,11	23,90	1,65	3,92	12,30	97,30	2,16	7,90
10	7,00	31,30	2,09	4,48	13,70	120,00	2,67	8,80
12	8,89	50,60	3,16	5,69	16,40	172,00	3,83	10,50
14	10,85	75,10	4,44	6,95	19,20	236,00	5,27	12,30
16	12,95	107,00	5,94	8,30	21,90	307,00	6,80	14,00
18	15,20	148,00	7,78	9,73	24,60	387,00	8,60	15,80
20	17,60	198,00	9,77	11,30	27,40	481,00	10,70	17,60
22	20,00	256,00	12,05	12,80	-	-	-	-
24	22,60	327,00	14,60	14,50	32,90	693,00	15,40	21,10
26	25,20	406,00	17,20	16,20	-	-	-	-
28	27,90	496,00	20,20	17,80	38,40	944,00	21,00	24,60

5.3. Calculation of the theoretical potential energy of sine waves

Potential energy has been defined as the energy of the body of water that is above the static level line.
In the sine wave hypothesis, we will determine this energy for a wavefront of length b [m] (Figure 5.5)[1].
We consider an elementary strip of width dx and height z (Figure 5.6).
Noting with G the weight of the water wave and with zcg its center of gravity:

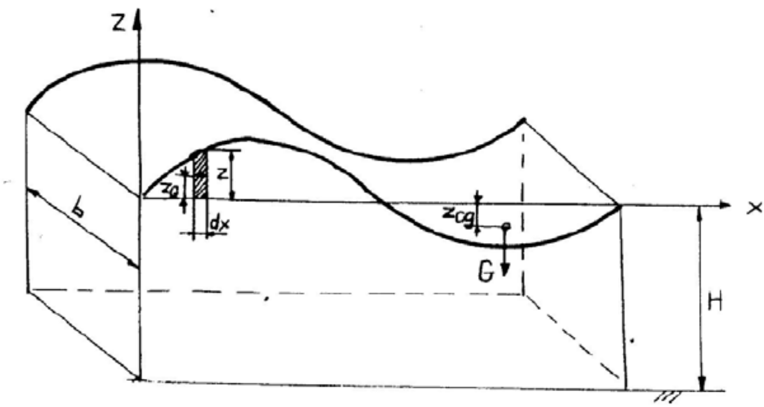


Figure 5.5.

$$E_{pot} = 2 \cdot G \cdot z_{cg} = 2\int_0^{\lambda/2} \gamma \cdot z \cdot b \cdot dx = \gamma \; b \int_0^{\lambda/2} z^2 dx. \qquad (5.30)$$

The wave being sinusoidal, we make the change of variable:

$$z = a \sin\left(2\pi \frac{x}{\lambda}\right),$$

Where $a = \frac{h}{2}, \quad x = c \cdot t = \frac{c}{\omega}\varphi.$

Result:

$$dx = \frac{c}{\omega} \cdot d\varphi = \frac{\lambda}{T \cdot \frac{2\pi}{T}} \cdot d\varphi = \frac{\lambda}{2\pi} \cdot d\varphi.$$

With this change of variable, the potential energy (equation 5.30) becomes:

$$E_{pot} = \gamma \; ba^2 \int_0^{\pi} \sin^2\left(\frac{2\pi \, x}{\lambda}\right) \cdot \frac{\lambda}{2\pi} \, d\varphi = \gamma \; ba^2 \frac{\lambda}{2\pi} \int_0^{\pi} \sin^2\varphi \; d\varphi; \qquad (5.31)$$

But

$$\int_0^{\pi} \sin^2 \varphi \, d\varphi = \int_0^{\pi} \frac{1-\cos^2}{2} d\varphi = \frac{\varphi}{2}\int_0^{\pi} - \frac{1}{4}\sin \; 2\varphi \int_0^{\pi} = \frac{\pi}{2}$$

And we get

$$E_{pot} = \frac{\gamma \, ba^2 \; \lambda}{4} = \frac{\gamma \, b \, h^2 \; \lambda}{16},$$

(5.32)

and the potential energy specific to the unit area:

$$e_{pot} = \frac{E_{pot}}{b\lambda} = \frac{\gamma \; h^2}{16}.$$

(5.33)

5.4. Calculation of theoretical kinetic energy

The kinetic energy is obtained from the expressions (5.15) of the components u and v of the velocity v. We will express the relations (15) in another way. For this we write the condition that at the surface, the small half-axis is half of the height of the wave a = h/ 2:

$$b = \frac{Ck}{\omega} sh\, kH = \frac{Ck}{\frac{2\pi}{T}} sh\, kH = Ck \cdot \frac{T}{2\pi} sh\, kH = \frac{h}{2} \quad ,$$

where from

$$Ck = \frac{\pi \, h}{T \, sh\, kH} \quad ,$$

which we replace in relations (5.15):

$$u = \frac{\pi \, h}{T \cdot sh kH} ch k\left(H - y\right) \sin\left(kx - \omega t\right);$$

$$v = \frac{\pi \, h}{T \cdot sh kH} sh k\left(H - y\right) \cdot \cos\left(kx - \omega t\right).$$

(5.34)

Specific kinetic energy (for b = 1 and λ = 1):

$$e_{cin} = \frac{1}{\lambda}\int_0^\lambda \int_0^H \rho \frac{V^2}{2} \cdot 1 \cdot dx\, dy = \frac{1}{\lambda}\int_0^\lambda \int_0^H \frac{\rho}{2}\left(u^2 + v^2\right) dx\, dy =$$

$$= \frac{1}{\lambda}\int_0^\lambda \int_0^H \frac{\rho}{2}\, \frac{\pi^2 h^2}{T^2\, sh kH}\left[ch^2\, k(H-y)\, \sin^2(kx-\omega t) + sh^2\, k(H-y)\cos^2(kx-\omega t)\right]$$

and considering that $ch^2\alpha - sh^2\alpha = 1$

$$e_{cin} = \frac{\rho \pi^2 h^2}{2\lambda T^2\, sh^2 kH}\int_0^H \left[\lambda\, sh^2\, k(H-y) + \frac{\lambda}{2} + \frac{1}{2k}\cdot 2\sin k\lambda \cdot \cos(k\lambda - 2\omega t)\right] dy =$$

$$= \frac{\rho \pi^2 h^2}{2\lambda T^2 sh^2 kH}\left\{\lambda\left[\frac{1}{2}\, \frac{sh 2k(H-y)}{2k}\,\Big|_0^H - \frac{1}{2}(0+H)\right] + \frac{\lambda H}{2} + \frac{H}{k}\sin k\lambda \cos(k\lambda - \omega t)\right\},$$

(5.35)

we get:

$$e_{cin} = \frac{\rho \pi^2 h^2}{2\lambda T^2\, sh^2\, kH}\left[\frac{\lambda}{4k}\, sh 2kH + \frac{H}{k}\sin k\lambda \cos(k\lambda - \omega t)\right].$$

(5.36)

The second term of the expression on the right is null. Indeed, since the values must be repeated after each wavelength, it follows that the value at x = 0 and t = 0 must also be found at x = λ and t=T, so

$$(kx - \omega t)\Big|_{\substack{x=0\\ t=0}} = (kx - \omega t)_{\substack{x=\lambda\\ t=T}};$$

Results

$$k = \frac{\omega T}{\lambda} = \frac{2\pi}{\lambda},$$

(5.37)

and so the second term in equation (5.36) is null.

$$e_{cin} = \frac{\rho \pi^2 h^2}{4\cdot \frac{2\pi}{\lambda}\cdot \lambda\, T^2\, sh^2\, kH}\cdot \frac{\lambda}{2}\, sh 2kH =$$

$$= \frac{\rho \pi^2 h^2}{8\pi\, T^2\, sh^2\, kH}\cdot \lambda\, shkH \cdot chkH = \frac{\rho\, \pi\, h^2\, \lambda}{8\, T^2\, th\, kH};$$

and highlighting the period T from the previous relations

$$T = \sqrt{\frac{2\pi\,\lambda}{g \cdot th\; kH}},$$

(5.38)

we obtain by replacing λ from the last expression of the kinetic energy

$$e_{cin} = \frac{\rho\; gh^2}{16} = \frac{\gamma\; h^2}{16} \;\;,$$

39)

and the energy of a front wave b [m] and of the wavelength λ:

$$E_{cin} = \frac{b\lambda\,\gamma\; h^2}{16}.$$

(5. 40)

Therefore, the kinetic energy of the wave is equal to the potential one, and considering the negligible capillary energy, we will obtain the total energy of the wave:

$$E_{tot} = E_{cin} + E_{pot} = \frac{b\lambda\,\gamma\; h^2}{8},$$

(5.41)

and the total specific energy:

$$e_{tot} = e_{cin} + e_{pot} = \frac{\gamma\; h^2}{8}.$$

(5.42)

From the deduced expressions it must be observed the special importance of the height h of the wave in its energy contribution.

5.5. Calculation of the theoretical power of waves

We will calculate the specific power P1 corresponding to the energy flow through a vertical surface of unit width (b = 1), normal on the direction of wave propagation, but up to the bottom of the basin. Integration must be done over a period of time and at depth H.

Therefore, for the wavefront unit:

$$P_1 = \frac{1}{T}\int_0^T \int_0^H F_p \cdot u(1 \cdot dy)\, dt,$$

(5.43)

where both the hydrodynamic pressure force F_p and the velocity vary with depth.

To express F_p we return to Bernoulli's equation (20) on the free surface:

$$u = \frac{p_o}{g} + \frac{v^2}{2} + \frac{\partial \varphi}{\partial t} = 0,$$

Where u= g.y

The term containing p_o is neglected. We will also neglect the term $v^2/2$. Measurements at the Black Sea, at H = 2.4 m and H = 6 m gave values v = 0.52 m / s and u <0.65 m / s. Therefore,

$\frac{v^2}{2} < 0{,}3\,\frac{m^2}{s^2}$ while the term $u = g\,y = g > 2{,}5\,\frac{m^2}{s^2}.$

We get:

$$-g\,y \cdot \frac{p}{\rho} + \frac{\partial \varphi}{\partial t} = 0, \qquad (5.44)$$

so the pressure force:

$$F_p = p + \rho\ gy = \rho \frac{\partial \varphi}{\partial t}.$$

The potential function ϕ is known (5.14). Therefore:

$$F_p = p + \rho\ g\,y = -\rho \frac{\partial}{\partial t}\left[C\, ch\, k(H-y)\cos(kx-\omega t)\right] =$$

$$= -\omega\rho\ C\, ch k(H-y)\cdot \sin(kx-\omega t) = \frac{2\pi^2 \rho\, h}{T^2 \frac{2\pi}{\lambda} sh kH} \cdot ch k(H-y)\cdot \sin(kx-\omega t).$$

(5.45)

We replace T^2:

$$F_p = \frac{\rho\, g\, h}{2\, ch\, kH}\, ch\, k(H-y)\, \sin(kx-\omega t).$$

The expression of power (5.43) becomes:

$$P_1 = \frac{1}{T}\int_0^T\int_0^H \left[\frac{\rho g h}{2\, ch kH} ch k(H-y)\cdot \sin(kx-\omega t)\right]\cdot\left[\frac{\pi h}{T\, sh kH}\right]\cdot$$

$$\cdot sh k(H-y)\cos(kx-\omega t)\, dy\, dt = \frac{1}{T}\int_0^T\int_0^H \frac{\pi \rho g h^2}{2T\, sh kH\, ch kH}\cdot$$

$$\cdot sh k(H-y)\, ch k(H-y)\cdot \sin(kx-\omega t)\cos(kx-\omega t)\cdot dt\cdot dy =$$

$$= -\frac{\rho^2 g h^2}{16}\cdot\frac{\lambda}{T}\left(1+\frac{2kH}{sh 2kH}\right) = \frac{g\cdot\gamma h^2}{16}\frac{\lambda}{T}\left(1+\frac{2\cdot\frac{2\pi}{\lambda}H}{sh 2\cdot\frac{2\pi H}{\lambda}}\right).$$

While

$$P_1 = \frac{g\gamma h^2}{16}\frac{\lambda}{T}\left(1+\frac{4\pi H/\lambda}{sh(4\pi H/\lambda)}\right) \qquad [W/m]. \tag{5.46}$$

This relationship can be simplified without getting too close:

- the term $\frac{4\pi H/\lambda}{sh(4\pi H/s)}$ tends to zero for very large H depths;
- - the wavelength is replaced by the value deducted from (5.27):

$\lambda = \frac{T^2\cdot g}{2\pi} th\frac{2\pi H}{\lambda}$, wherein $th\frac{2\pi H}{\lambda}$ tends to 1 for H large enough.

We get:

$$P_1 = \frac{g^2\gamma h^2 T}{32\pi} \sim h^2 T[kw/m]. \tag{5.47}$$

The conclusion of the relation (5.47) is that the power provided by the wave is very much dependent on the height of the wave, being also influenced by the period of the phenomenon.

5.6. Raising the average sea level due to waves

In the previous calculations, the parameter H (water depth) was also used, defined as the vertical distance from the meridian plane of the wave to the bottom of the sea basin in which the undulating movement is manifested in the form of waves.
Under the action of the wind, with the formation of waves, in each point there is a̋ swelling ″ of water, an increase of the average level compared to the static level. This elevation varies with the intensity of the turbulent water in the pool. Therefore, it was necessary to enter the parameter s0, called the average level rise.
Noting the static depth with H_s, it follows that the depth H from the wave energy formula:

$$H = H_s + s_o. \tag{5.48}$$

The value of H_s is given in the bathymetric curves of the sea charts. To calculate the elevation, use the formula:

$$s_o = \frac{\pi h^2}{\lambda} cth \frac{2\pi H}{\lambda}. \tag{5.49}$$

In this formula if H_s increases and the fraction $2\pi H / \lambda$ reaches the value 6, then $cth \frac{2\pi H}{\lambda} \to 1,$ and the formula is simplified:

$$s_o = \frac{\pi h^2}{\lambda} .$$

As an order of magnitude, the uplift s_0 on the Romanian coast:

- la $h = 0{,}5\ m$ si $\lambda = 7 m \rightarrow so = 0{,}11\ m;$
- la $h = 6\ m$ si $\lambda = 100\ m \rightarrow so = 1{,}13\ m.$

5.7. The critical depth of the basin in which the waves act

The depth at which the orbital motion is disturbed due to the presence of the seabed is called the critical depth, H_{cr}. Disruption of orbital motion occurs when the velocity c of the wave decreases, hindering the motion of the wave particle in orbit and preventing it from returning to its own orbit.

We will see what is the order of magnitude of the orbital velocity vs. and the speed. Relation (5.29) of speed:

$$c = \sqrt{\frac{g\lambda}{2\pi} th \frac{2\pi H}{\lambda}},$$

becomes for the sufficiently deep waters $c = \sqrt{\frac{g\lambda}{2\pi}}$, because

$$th \frac{2\pi H}{\lambda} \to 1,$$

and orbital velocity

$$v_s = \frac{2\pi r}{T} = \frac{\pi h}{T}.$$

In this case will be two numerical situations:

1. $h = 0{,}5\ m; \quad \lambda = 7\ m; \quad T = 2\ s,$

It will get

$c = 3{,}3\ m/s$

$v_s = 0{,}78\ m/s;$

2. $h = 6\ m; \quad \lambda = 100\ m; \quad T = 8{,}3\ s,$ .It will get

$c = 12{,}5\ m/s$

$v_s = 2{,}27\ m/s.$

Therefore, at sufficiently deep depths, the speed is 4 to 6 times higher than the orbital speed. If the water depth decreases, wave braking occurs (speed decreases) and the two speeds can become equal. In this case, the surge (breaking of the wave), represented in Figure 5.6[1]:

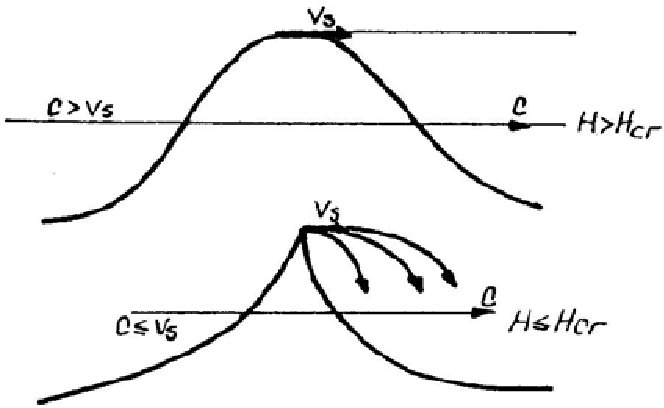


Figure 5.6. Wave surge.[1]

The semi-empirical expression of the critical depth is:

$$H_{cr} = \frac{T\sqrt{gh}}{4\pi} \ln \frac{T\sqrt{g} + \pi\sqrt{4h}}{T\sqrt{g} - \pi\sqrt{4h}}, \tag{5.50}$$

or, considering that $\pi \sim \sqrt{g}$:

$$H_{cr} = \frac{T\sqrt{h}}{4} \ln \frac{T + \sqrt{4h}}{T - \sqrt{4h}}.$$

It will appreciate the order of magnitude of the critical depth for two concrete examples:

1. $h = 9\,m$; $T = 15\,s$, the maximum wave at the Black Sea;

$$H_{cr} = \frac{15\sqrt{9{,}81 \cdot 9}}{4 \cdot 3{,}14} \cdot \ln \frac{15\sqrt{9{,}81} + 3{,}14\sqrt{4 \cdot 9}}{15\sqrt{9{,}81} - 3{,}14\sqrt{4 \cdot 9}} = 9{,}54\ m = 1{,}06\ h;$$

2. $h = 4\,m;\ \ T = 8{,}7\ s,$

,

$$H_{cr} = \frac{8{,}7\sqrt{9{,}81\cdot 4}}{4\cdot 3{,}14}\cdot \ln\frac{8{,}7\sqrt{\ } + 3{,}14\sqrt{4\cdot 4}}{8{,}7\sqrt{9{,}81} - 3{,}14\sqrt{4\cdot 4}} = 4{,}33\ m = 1{,}08\,h.$$

Therefore, H_{cr} ~ 1.1 h according to formula (5.50). In reality, due to secondary waves:

$H_{cr} = 1{,}35\,h,$

value with which to work in design calculations.

5.8. REFERENCES

1. Panaitescu F.V., Theoretical and experimental treatment of BLACK SEA waves. MONOGRAPH (Tratarea teoretica si experimentala a valurilor din MAREA NEAGRA. MONOGRAFIE), Publishing House NAUTICA, Constanta, Romania, ISBN 978-606-681-088-X, 2016.

5.9.*<u>Practical class 5.</u>* Evaluation of the energy potential of the waves based on the hydrometeorological regime. Introduction in modeling software (eg. MIKE).

5.9.1. Evaluation of the energy potential of the waves based on the hydrometeorological regime.

In the concrete case of designing a power plant to convert wave energy into electricity, a study is needed on the energy potential of waves in that area. Since the factor that most determines the value of the wave energy is its height, h , it is necessary to know what is the optimal value of the waves we can count on. The peculiarity of all known installations is that they take over with optimal results a relatively narrow range of height h. To design the installation for a low wave height of 0.3 m, for example, means to lose energy from large waves, which although appear less frequently, they have a much higher energy intake. If we calculate the energy of a wave of h = 6 m, their ratio is:

$$\frac{E\Big|_{h_1=6}}{E\Big|_{h_2=0,3}} = \frac{\frac{\gamma h_1^2}{8}}{\frac{\gamma h_2^2}{8}} = \left(\frac{h_1}{h_2}\right)^2 = \left(\frac{6}{0,3}\right)^2 = 400 . \quad s$$

1.

On the other hand, to design the installation for taking over large amplitude waves, means to lose the energy of small waves which, although low, manifest themselves in a longer period of time.
Another factor to be studied is the predominant direction of the winds and, implicitly, of the waves in the studied sector, in order to place the sensor perpendicular to the direction of the wave front (the vast majority of the sensors take unidirectional energy).
Given the somewhat random nature of the waves, the period of observation of the hydrometeorological regime must be long enough, of the order of years, to benefit from complete data.
In the coastal area of our country we benefit from such observations. They date back to September 1959, when the State Water Council installed the first wave prospectometer in Constanta -on the 9-meter isobath- with which systematic measurements began on the wave elements: height, period, wavelength, speed and direction. The second prospector was placed at Mangalia in December 1967, also at the 9-meter isobath; the measurements are daily, at 7 00, 13 00, 19 00.
The initial device consisted of an optical aiming system, telemetry type, the parts being materialized by buoys. Later, the buoys were replaced with fixed vertical stages.
Observatory which looks at a field of waves captures without difficulty, in its visual spectrum, the large and distinct individual waves: their height hmax, is the measured one. However, the wave field is the set of waves produced by the wind on the surface of the water: each wave “i” has distinct elements hi, λi, Ti, ci, being different from the others; the statistical distribution of all waves in the wave field is random.
Based on the measurements performed by the Institute of Meteorology and Hydrology between 1959-1974 at the Constanta site, table 1 shows the frequency (%) and wind speed (m / s) on the main directions of action:

Table 1. Frequency (%) and wind speed (m / s) on the main directions of action

TOTAL	dIRECTIONS									TOTAL
	N	NE	E	SE	S	SV	V	NV	Calm	100 000
calm	-	-	-	-	-	-	-	-	8,670	8,670
0 - 1,0	0,570	0,628	0,565	0,900	0,940	0,882	1,345	0,940	-	6,770
1,1 - 3,0	1,760	2,205	1,755	3,470	3,210	2,910	4,520	3,830	-	23,660
3,1 - 5,0	2,266	2,739	1,896	3,727	3,405	2,690	4,492	3,785	-	25,000
5,1 -10,0	6,065	5,710	1,870	3,520	3,179	1,660	4,512	4,024	-	30,540
10,1-13,0	1,090	1,000	0,190	0,087	0,071	0,075	0,239	0,290	-	3,043
13,1 - 15,0	0,440	0,430	0,073	0,016	0,010	0,041	0,104	0,059	-	1,173
15,1-17,0	0,275	0,272	0,030	0,005	0,005	0,005	0,027	0,029	-	0,648
17,1-22,0	0,157	0,214	0,034	0,010	-	0,007	0,011	0,023	-	0,456
22,1-28,0	0,005	0,006	0,007	0,005	-	-	-	-	-	0,023
28,0	0,002	0,016	-	-	-	-	-	-	-	0,018
TOTAL	12,630	13,220	6,420	11,740	10,820	8,270	15,250	12,980	8,670	100 000

The conclusion is that the arrangement of the energy capture front would be optimal on the N-E direction with 13.22% of the total. Although the predominant winds are manifested in the westerly direction (15.25%), this direction cannot be used because it is manifested from the land and therefore there is no necessary fetch (fig. 1).

Tables 2 and 3 show the distribution of the monthly average value of the h_{max} height of the waves in Constanta (1970 - 1974), respectively Mangalia (1972-1974). The averages presented indicate a higher energy potential in Constanta than in Mangalia. There is also an unequal distribution during the year, with higher values in the winter months, which is advantageous because in winter the energy demand is higher:

Table 2. Distribution of the monthly average value of the hmax height of the waves in Constanta [1]

Anul/ Luna	I	II	III	IV	V	VI	VII	III	IX	X	XI	XII
1970	0,52	0,80	0,78	0,38	0,32	0,21	0,28	0,24	0,36	0,45	0,47	0,31
1971	0,74	0,42	0,79	0,43	0,36	0,19	0,30	0,38	0,51	0,64	0,33	0,29
1972	1,22	0,45	0,50	0,41	0,27	0,30	0,38	0,32	0,45	0,77	0,24	0,68
1973	0,77	0,13	0,52	0,32	0,19	0,,34	0,19	0,48	0,,74	0,61	0,32	0,18
1974	0,73	0,73	0,77	0,62	0,18	0,33	0,22	0,76	0,41	0,44	0,46	0,41
Medi a	0,80	0,51	0,67	0,42	0,27	0,27	0,27	0,44	0,49	0,58	0,37	0,37

Table 3. Distribution of the monthly average value of the hmax height of the waves at Mangalia [1]

Anul/ Luna	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1972	0,86	0,29	0,45	0,24	0,16	0,11	0,19	0,11	0,22	0,50	0,10	0,18
1973	0,50	0,12	0,36	0,16	0,03	0,18	0,05	0,13	0,38	0,33	0,16	0,03
1974	0,44	0,39	0,30	0,22	0,07	0,04	0,02	0,20	0,08	0,12	0,21	0,24
Media	0,60	0,27	0,38	0,20	0,08	0,11	0,09	0,15	0,23	0,32	0,16	0,18

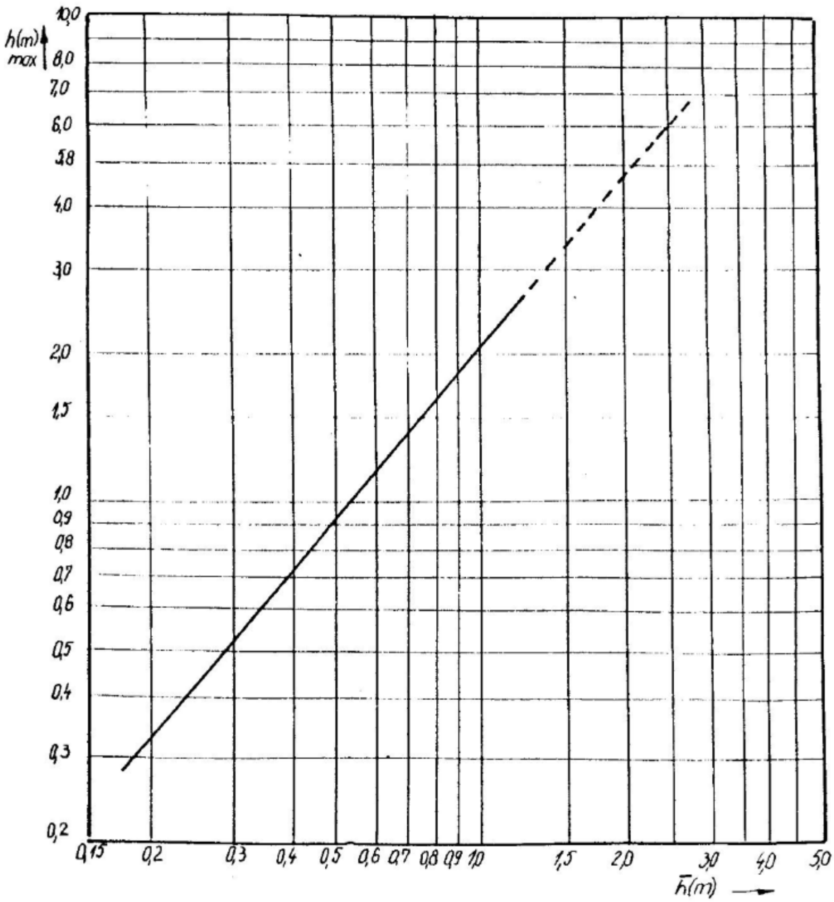


Figure 1. Correlation between the maximum measured height and the average height of the wave field h

All tables are calculated with the measured hmax height. The correlation between the maximum measured height and the average height of the wave field h is given in fig. 1. The data provided show that calm situations (waves below h = 0.2 m), represent 54% of the year in Constanta and 73% of the time in Mangalia.

The general average of the measurements performed, in number of 5200 observations in Constanta and 3270 in Mangalia, including calm, indicates a value of average hmax: hmax = 0.45 m in Constanta and

h_{max} = 0.23 m in Mangalia. Excluding the calm period, the average value reaches:
h_{max} = 0.99 m at Constanta
and of
h_{max} = 0.53 m at Mangalia.
Based on the mentioned measurements, the dependence of the wave parameters was plotted. Thus, in figure 2 is represented the correlation between the maximum measured height hmax (m) and the wavelength λ (m).

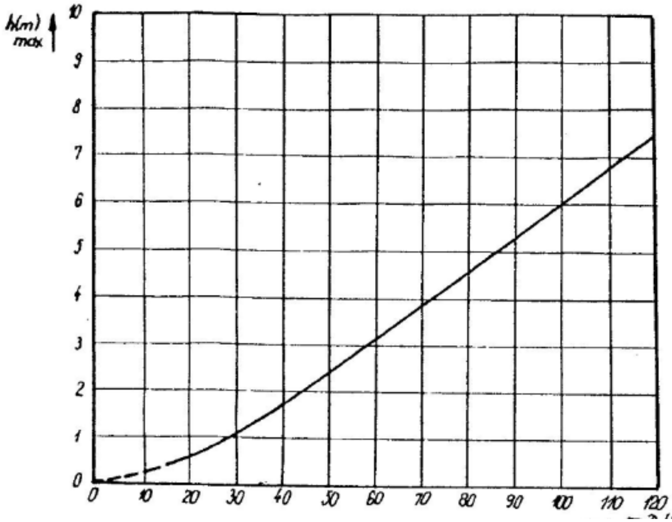


Figure 2. Correlation between the maximum measured height hmax (m) and the wavelength λ (m)

Figure 3 shows the dependence between the maximum measured height hmax (m) and the average wave period of the wave field T (s).

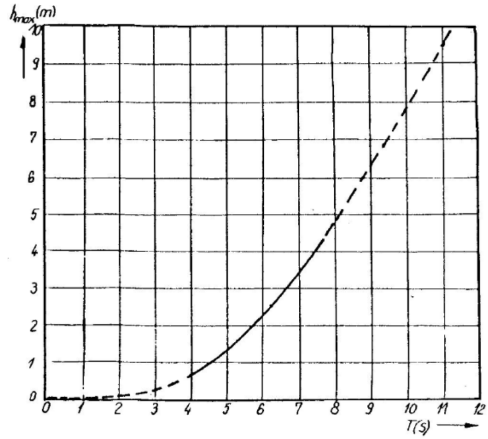


Figure 3. Dependence between the maximum measured height hmax (m) and the average wave period of the wave field T (s)

Figure 4 shows the duration curve of the wave height at Constanta. It is observed that waves over 1.5 m have a presence of 10% of the annual time, and waves over 3 m have a presence of only 1% of the year:

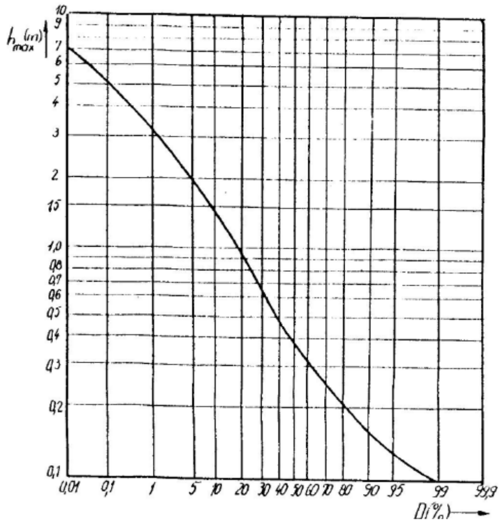


Figure 4. Duration curve of the wave height at Constanta

With the help of the calculation relations of the kinetic, potential energy and of the wave power, also on the basis of the duration curve from figure 4, the graphs can be drawn, for 1 m of wave front:
-the power curve produced by P waves (kW) as a function of the maximum measured height hmax (m) represented in figure 5;

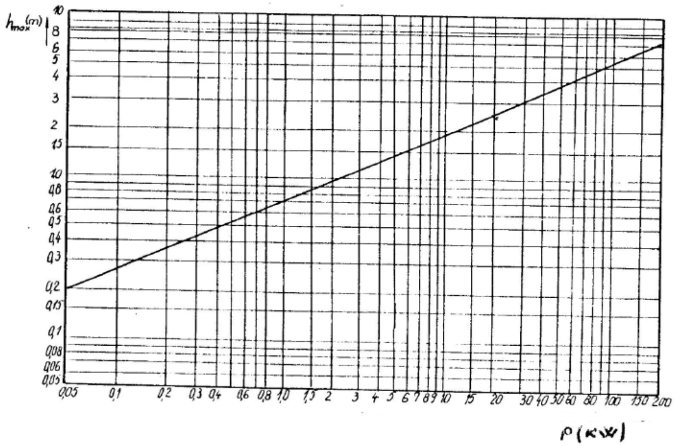


Figure 5. Power curve produced by P waves (kW) as a function of maximum height
measured hmax (m)

- the duration curve of the power produced by P waves (kW) represented in figure 6;
- the curve of the energy produced by waves E (kWh) depending on the ensured height (as duration) hmax (m) of the waves represented in figure 7;
-the specific E / P energy production curve (kWh / kW) as a function of the wave height hmax (m) represented in figure 8:

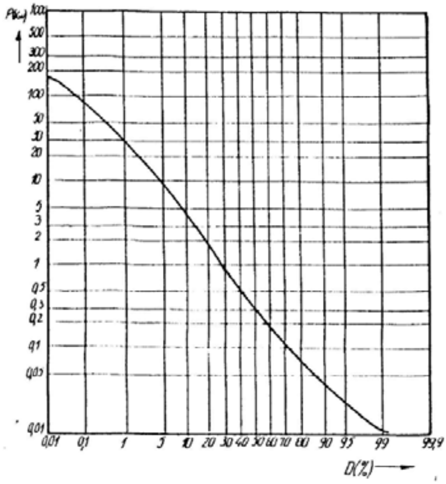


Figure 6. P-wave power duration curve (kW)

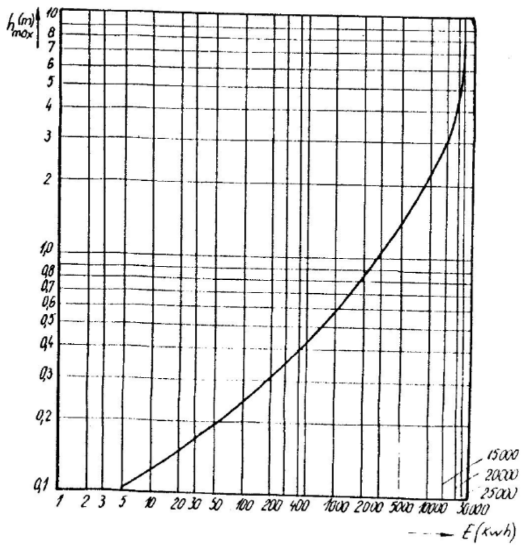


Figure 7. Wave energy curve E (kWh) as a function of the assured height (in duration) hmax (m) of the waves

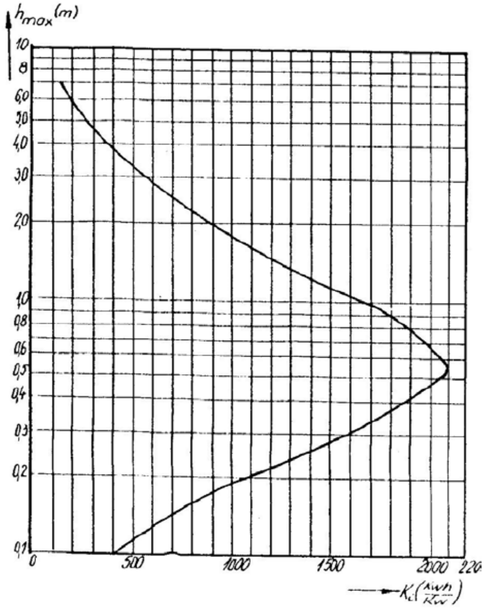


Figure 8. Specific energy production curve E / P (kWh / kW) as a function of wave height h_{max} (m)

From this last figure, obtained on the basis of the data from figures 7 and 5, the optimal height of the wave for the design of the sensor is obtained, which is around:h_{max} = 0.55 m, which corresponds to an average value h of the wave field (figure 2) h≅0.35 m.

Comparing the values obtained above with those existing in other locations around the world:

-in the Sea of Japan, h_{max}, = 170, including calm, which represents 20% of the annual time;

-in the USA. (in the Atlantic), h_{max}, = 100, including calm;

-in the Mediterranean Sea (Algeria), hmmax, = 127, including calm.

The constant benefits from: h_{max}, = 045, including calm, which represents 54% of the annual time, so relatively low values of energy potential.

For example, tables 4 and 5 show the frequency and average wind speed, respectively the wind distribution during 1995, in Constanta; these values are very close to those presented in table 1:

Table 4. Frequency (%) and average wind speed (m / s) in Constanta

Dir.	Parametri	Ian.	Feb.	Mart.	Apr.	Mai	Iunie	Iulie	Aug.	Sept.	Oct.	Nov.	Dec.	Media
N	Frecventa	18,5	20,5	15,6	9,5	6,3	7,5	9,3	10,7	13,7	15,6	13,8	17,4	13,4
	Media vitezei	8,4	8,2	7,0	5,6	5,3	5,0	5,3	5,6	6,5	7,2	7,4	8,2	6,6
NE	Frecventa	10,2	16,1	12,8	13,5	12,7	10,2	11,9	13,2	14,2	18,8	9,2	6,0	12,6
	Media vitezei	9,0	7,3	7,1	5,7	5,9	5,1	5,3	5,1	6,3	7,0	7,2	7,9	6,6
E	Frecventa	3,2	3,7	5,4	7,3	7,5	7,7	7,5	8,9	9,3	6,0	5,4	2,4	6,2
	Media vitezei	6,4	4,7	4,4	5,9	4,1	3,8	3,9	3,8	4,3	5,0	6,7	7,7	4,9
SE	Frecventa	4,9	5,8	11,9	17,7	18,7	16,8	13,1	13,0	12,2	11,6	8,1	3,5	11,4
	Media vitezei	4,7	3,7	4,3	4,5	4,2	4,2	4,0	3,9	4,4	4,5	4,1	5,2	4,3
S	Frecventa	9,5	11,3	11,0	16,2	15,0	13,6	12,5	9,3	9,2	9,6	10,9	9,2	11,4
	Media vitezei	4,2	4,5	4,6	4,7	4,2	3,9	3,8	3,7	3,8	4,3	4,2	5,2	4,3
SV	Frecventa	7,2	7,5	6,9	6,5	6,1	6,2	5,8	5,7	6,3	8,4	10,0	10,5	7,3
	Media vitezei	3,8	4,4	4,3	4,6	4,2	3,2	3,0	3,1	3,2	3,2	3,7	4,6	3,9
V	Frecventa	20,6	14,8	11,1	11,0	10,5	14,8	13,3	12,8	12,6	13,1	21,4	24,5	15,1
	Media vitezei	4,7	4,9	4,6	4,7	4,3	3,8	4,2	3,6	3,5	3,9	4,5	5,2	4,3
NV	Frecventa	17,7	11,8	9,3	8,1	9,1	11,0	14,2	13,7	10,8	9,4	11,2	18,7	12,1
	Viteza medie	5,2	5,1	4,8	4,5	4,5	4,2	4,3	4,2	3,9	4,6	5,2	5,4	4,7

Table 5. Wind speed distribution in Constanta

Wind speed (m/s)	Ian.	Feb.	Mart.	Apr.	Mai	Iunie	Iulie	Aug.	Sept.	Oct.	Nov.	Dec.	Average
0 - 1	13,2	8,0	16,1	14,9	18,2	19,8	19,8	19,3	20,6	18,3	14,8	12,1	16,3
2 - 5	41,0	48,1	44,4	53,2	53,6	56,2	56,7	53,5	51,4	47,0	47,4	47,6	49,8
6 - 10	36,4	36,0	33,6	29,0	25,8	21,6	23,0	25,3	27,4	33,2	31,2	33,7	29,6
11 - 15	7,1	6,9	4,7	2,5	2,1	1,2	0,8	0,6	2,6	4,4	4,4	4,5	3,5
16 - 20	2,1	1,9	1,2	0,4	0,3	0,2	0,2	0,0	0,3	0,6	1,9	1,9	0,8
21 - 28	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,2	0,0
29 - 40	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

It should be noted that these calculations, although based on older measurements, are also valid for the current situation.

5.10. ***Lab 5*****. Introduction in modeling software (eg. MIKE). Initiation in the use of waves software tools.**

5.10.1.MATHEMATICAL MODELING IN MIKE [3]

1 Introduction

Mike by DHI is a software dedicated to the manegement of waters. This software has a variety of components, but the one we will be using *is MIKE 21 Flow Model* – which provides the basis for process calculations, performed in many other modules such as sediment and mud transport, thermal energy and suspended solids transport, oil spill, agent-based modeling and ecology, but it can also be used as standalone application. The module simulates the inconsistant flow taking into account the bathymetry, the sources and the external forces. With the help of this model, we will eventually evaluate the hydrographic conditions of the work area.

2 The FM hydrodynamic flow model

2.1 Work area

1. Creating a Mesh

Creating a mesh is a very important step in terms of modeling with the help of the MIKE by DHI software. This file contains informations about: grid calculation, water depths in various areas and extreme conditions.

The following application uses the Oresund bridge, the bridge that connects Denmark to Sweden, as an area of interest (Figure 1).

The construction of this bridge encountered some difficulties, namely those related to maintaining the aquatic environment of the Baltic Sea intact.

The area of interest for this application is presented in Figure 2.

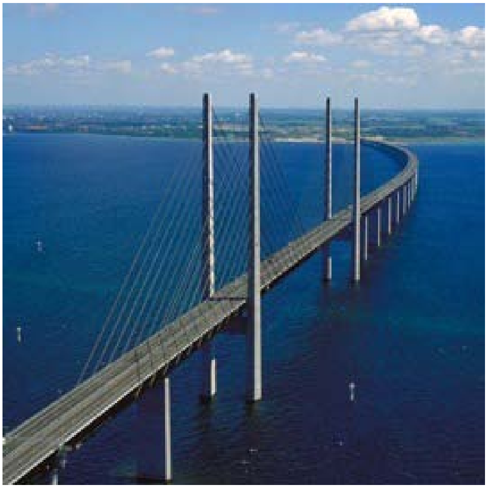


Figure 1 Oresund, Denmark

Figure 2 Oresund Map (www.wikipedia.ro)

For mesh building, data on shoreline and water level depths are required. This files have a “.xyz” extension.

1.1 Creating a “mdf” file by using “xyz” file data.

A mesh type file contains information about water depths: we will create it by using the Mesh Generator tool in Mike Zero. (File – New – File – Mesh Generator) (Figure 3).

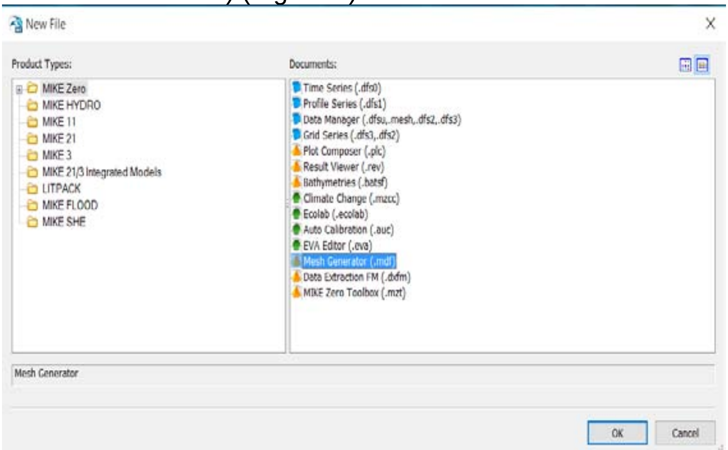


Figure 3 *Mesh-Generator – Mike Zero*

After opening this tool, a projection system will be specified: for this application we choose UTM 33. After establishing the projection system, we obtain work areas.

Once the work space is established, data about shoreline from ASCII type files will be added. (Data – *Import Boundary* – Open land.xyz). It will be chosen as the LONG/LAT projection system, the system in which the measurements from the xyz file types are projected, and will then be converted to the system chosen in the previous steps. The shoreline will be obtained Figure 4).

The next step is to transform the data into a set of data with a selected domain that can be triangulated (diving the domain in several triangles).

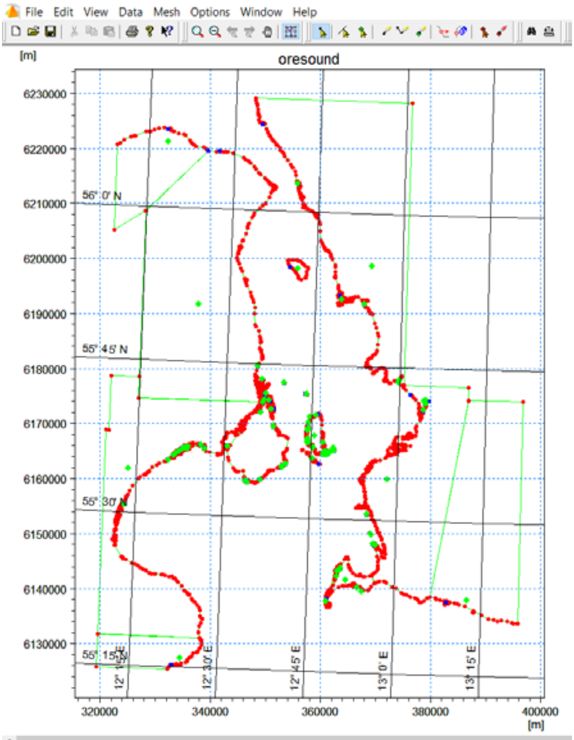


Figure 4 Shoreline after adding the first data

2.2 Modifying boundary conditions with an area that can be triangulated

After the first data has been added a closed domain will be obtained (the green lines will connect the dots). In order for this to happen, it is necessary that the red and blue dots located outside of the domain to be erased.

The northern and southern boundary between Denmark and Sweden will be defined by connecting the dots. For the northern area we will select the line which connects the two dots by double-clicking on it and we will choose Properties. We will insert the number 2 till we complete the whole line. We do the same for the Southern line, but this time we will complete with the number 3 on the whole line. These assignments of 2 and 3 are used to differentiate the types of boundary conditions, as the northern boundary is different from the southern boundary. Mesh Generator will automatically assign the number 1 to the other lines.

At this point, the area is closed and can be triangulated, but first a uniformization of the area is required. The triangulation of a zone starts at the boundaries of the polygon, thus the number of elements (triangles) generated depend directly on the number of nodes and vertices that the polygon has. Thus, it is necessary that they are redistributed with a small distance in between them. (We will delete a few nodes and vertices without changing the shape of the polygon). After this step is completed, we will save the file as: Oresound.mdf. In this moment the mesh is crated.

2.3 Domain triangulation

The following step is to divide the domain into elements as small as possible. The enclosed area (islands) that is not needed in this step will be marked. (a green dot will be fixed inside the areas and they will not be triangulated)

For triangulation we select in the working window: Mesh – Generated Mesh. The following options are used:

- Maximum surface of the area elements: 1500000 m^2
- Smallest available angle: 30
- Maximum number of nodes: 6000

After completing this process, the Smooth tool is used to even out the area. For this application we will use a 100 times smoothing option. The resulting mesh can be seen in Figure 5.

Next, the bathymetry of the area will be added. (Data – Manage Scatter Data -Add – Water.xyz). LONG/LAT is specified. After adding them, they will be interpolated: Mesh – Interpolate. (Figure 6)

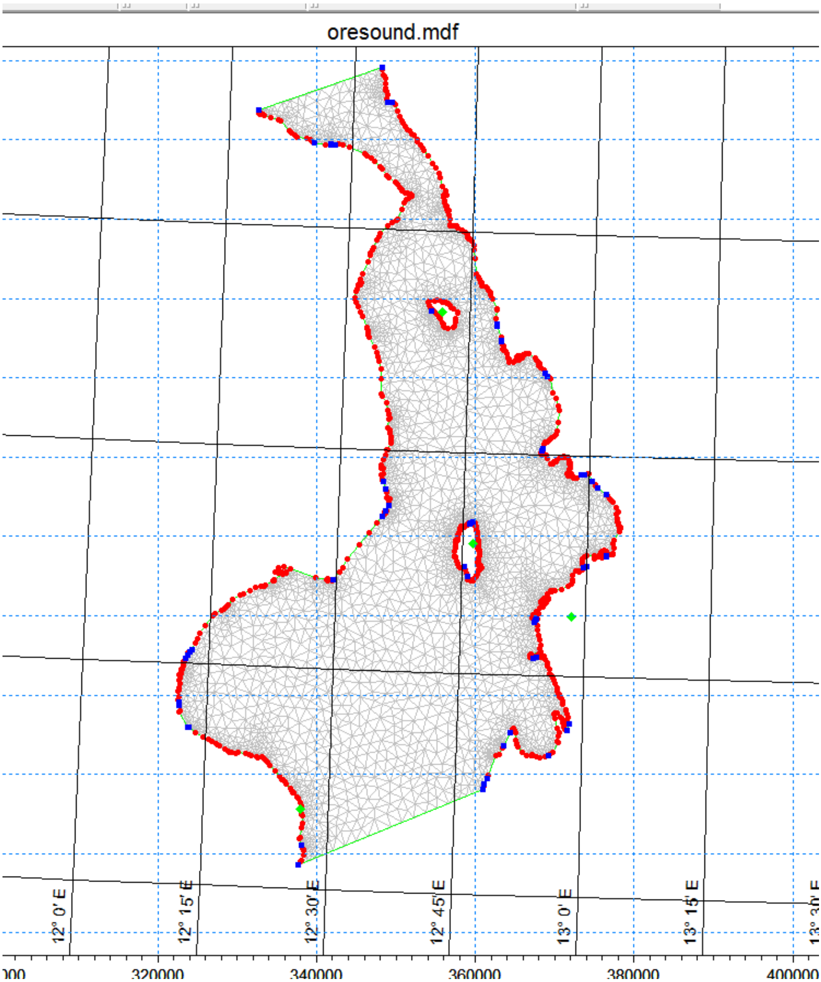


Figure 5 Area obtained after triangulation and smoothing

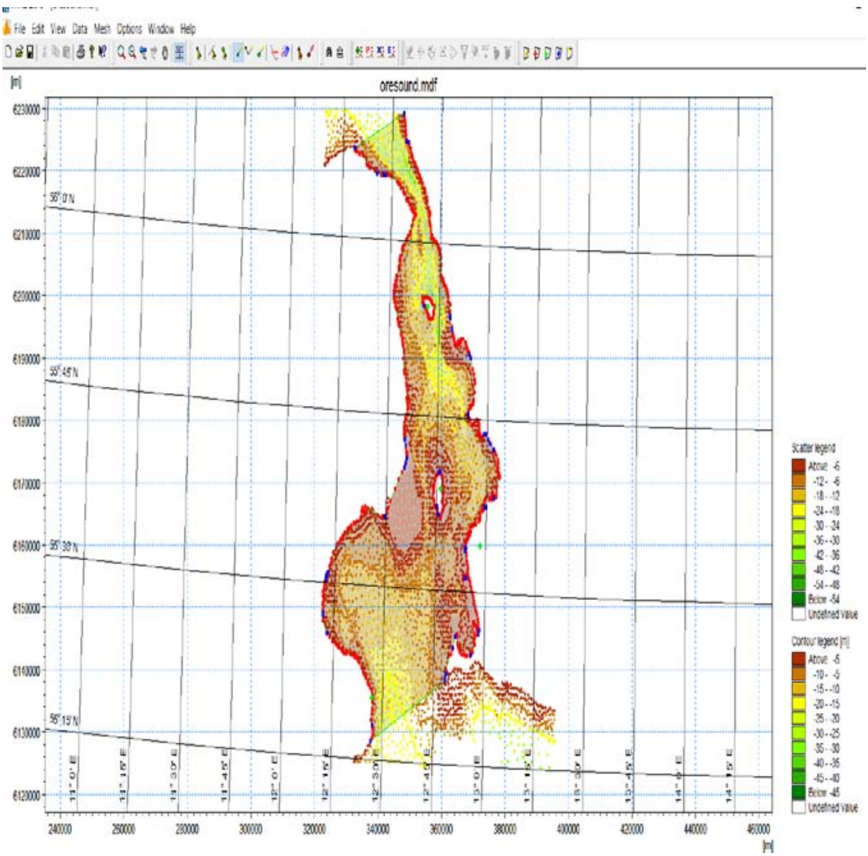


Figure 6 Work area after adding bathymetry

After completing these steps, the data will be exported to a file that will be used in the following steps. (Mesh – Export Mesh). Save the end result.

The result can be seen in *Data viewer*, Figure 7, or in *Mike Animator Plus*, Figure 8.

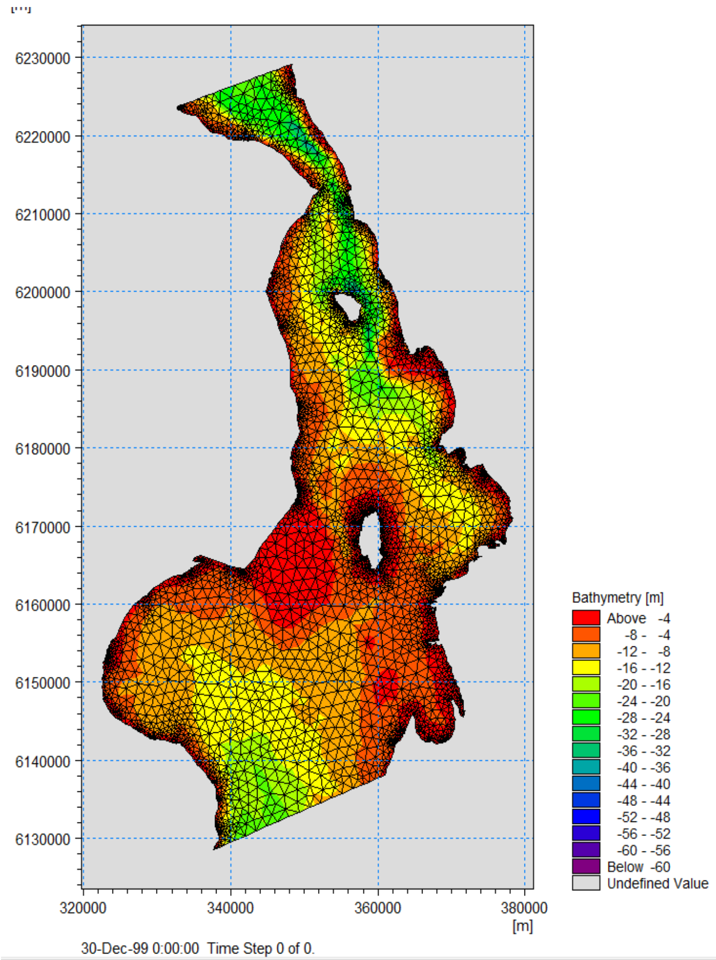


Figure 7 Oresound file (presented in *Data Viewer*)

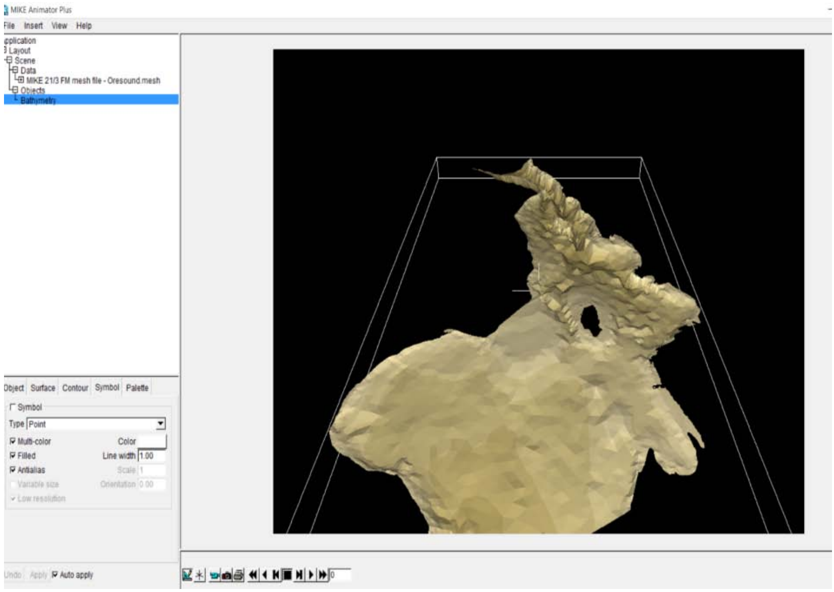


Figure 8 Oresound.mesh file (presented in Mike Animator Plus)

2.4 Defining the initial parameters for the simulation process in Mike 21 Flow Model FM

Before starting the simulation in MIKE 21, the initial data is obtained from the measurements. The measurements are from 1993 and they refer to limit conditions for the water level in the Oresound Bridge area and data related to wind parameters in the Kastrup Airport area (Copenhagen, Denmark).

To generate these initial parameters, we will be using different tools in MIKE Zero.

2.5. Generating limit conditions for the water level

The measurements were made with the help of a station fixed in the area. For this application, water level measurements indicate that the variations along the shoreline are significant, therefore water level limits must be specified as line series (dfs 1 data file) in which an interpolation between two measurements is made at each border.

This way, a dfs1 file, which contains variations of the water level, will be created based on the records from 4 stations.

- **Creating a “Time Series” file**

Open Series Editor Time in MIKE Zero (*File – New – File – Time Series – Ascii Template*). In the following, we will add the *waterlevel_hornbaek.txt* file, by selecting "*Equidistant Calendar Axis*" (equidistant time stages must exist, if the raw data has time gaps without measurements, these must be completed for example by interpolation) after which we click OK. Right-click on the data generated in the Time Series Editor and select properties: choose "*Water Level*" at Item Type. The dfs0 file is created and can be saved as *waterlevel_hornbaek.dfs0*. Repeat the same steps for the remaining 3 stations.

For graphic representation, these data series can be visualized in *Mike Zero – Plot Composer – Plot – Insert a new plot object – Time Series Plot.*

Choose the file by double-clicking on the dotted square on the right. Multiple files can be added for the same area. Some properties, such as color, can be changed in the *Time Series Plot Properties*. What results for a single station can be seen in Figure 9, Figure 10.a, Figure 10.b.

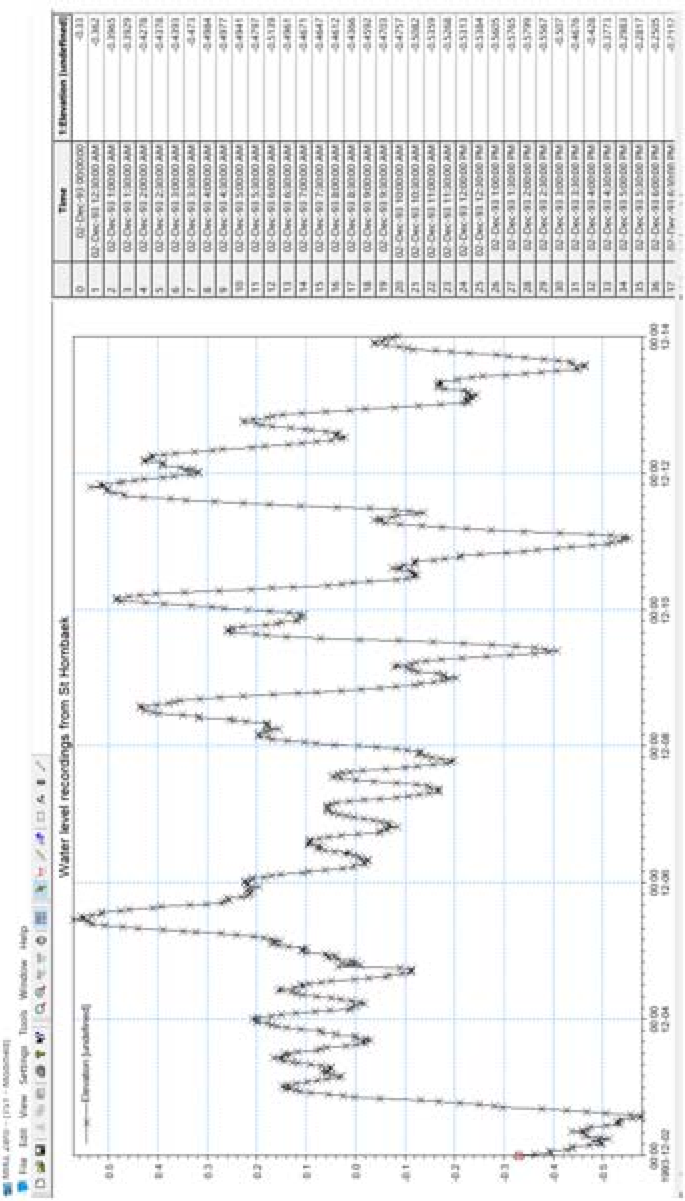


Figure 9 Data from the Hornbaek station

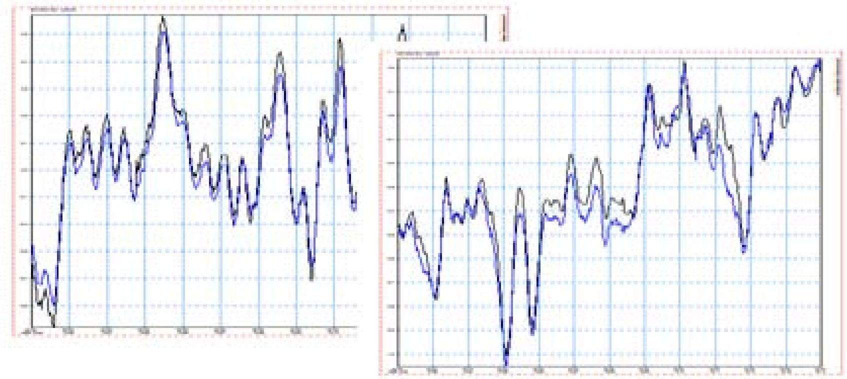


Figure 10 Comparison between the data from the first 2 stations:

Hornbaek and Viken (a) (right)

And the other two stations- Skanor and Rodvig (b) (left)

2.5.1 Limit conditions

The next step is to create line series using the time series generated earlier. Load in MIKE Zero – Profile Series and select “Blank”.

In the next window we will add the following information:

- Title: Water Level North Boundary [m]
- Axis Type: Equidistant Calendar Axis
- Start Time: 12/2/1993 12:00:00 AM
- Time Step: (sec): 1800
- No. of timesteps: 577
- Number of Grid Points: 2
- Grid Step (m): 9200 (is represented by the width of the boundaries, but is not absolutely necessary since Mike 21 interpolates the line series to the nodes that are on the boundary, regardless of the distance).

After this information has been added, in the window that appears, an empty table will be located on the right side. In this table, we will add for the first column the data obtained from the *waterlever.hornbaek.dfs0* document, and for the second column we will add the files obtained from the *waterlevel_viken.dfs0* file. The resulting file will be named *waterlevel_north.dfs1*. (Figure 11).

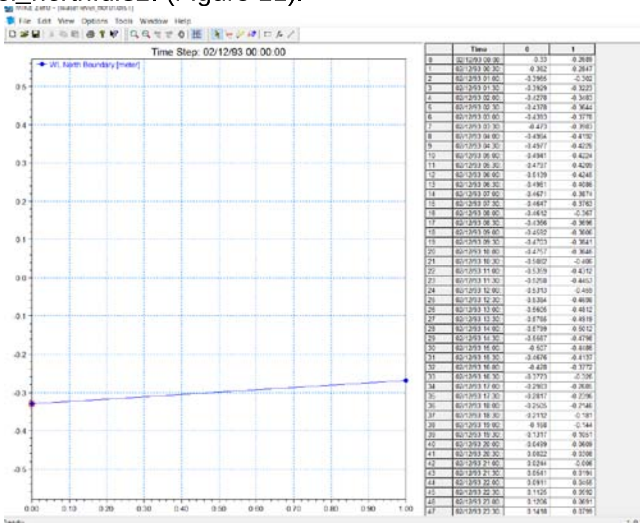
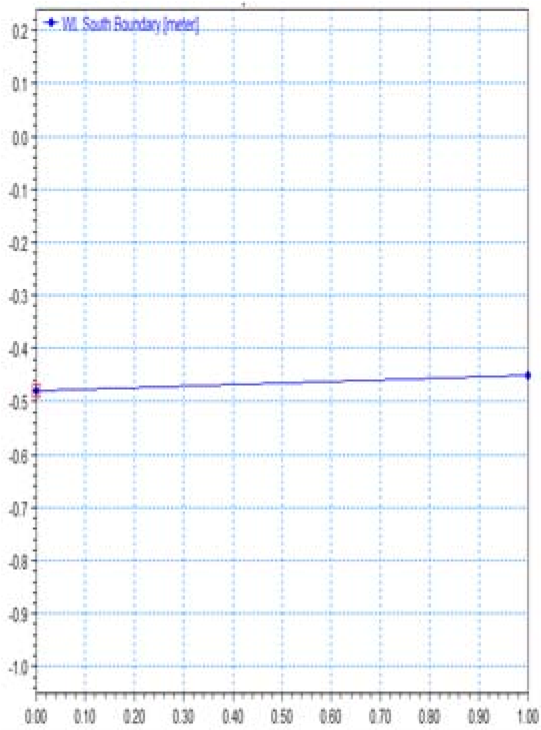


Figure 11 Line series for the northern boundary

Repeat the same steps for the southern boundary with similar information, except for the Title information (Water Level South Boundary [m]) and Grid Step (we will change it by 33500 m). Data from the files from the other two stations (*waterlevel_rodvig.dfs0* and *waterlevel_skanor.dfs0*) will be added. The final file named *waterlevel_south.dfs1* is saved (Figure 12).



	Time	0	1
0	02/12/93 00:00	-0.4793	-0.45
1	02/12/93 00:30	-0.49	-0.4571
2	02/12/93 01:00	-0.482	-0.4621
3	02/12/93 01:30	-0.4993	-0.4756
4	02/12/93 02:00	-0.482	-0.4905
5	02/12/93 02:30	-0.5107	-0.5051
6	02/12/93 03:00	-0.51	-0.5196
7	02/12/93 03:30	-0.492	-0.5151
8	02/12/93 04:00	-0.4993	-0.5047
9	02/12/93 04:30	-0.4713	-0.4866
10	02/12/93 05:00	-0.4613	-0.4669
11	02/12/93 05:30	-0.4527	-0.4551
12	02/12/93 06:00	-0.4593	-0.4453
13	02/12/93 06:30	-0.4507	-0.439
14	02/12/93 07:00	-0.46	-0.4339
15	02/12/93 07:30	-0.4787	-0.4247
16	02/12/93 08:00	-0.4713	-0.4147
17	02/12/93 08:30	-0.4513	-0.413
18	02/12/93 09:00	-0.432	-0.413
19	02/12/93 09:30	-0.46	-0.4089
20	02/12/93 10:00	-0.4693	-0.4038
21	02/12/93 10:30	-0.4793	-0.4155
22	02/12/93 11:00	-0.4893	-0.4305
23	02/12/93 11:30	-0.5287	-0.4494
24	02/12/93 12:00	-0.5213	-0.4691
25	02/12/93 12:30	-0.568	-0.4893
26	02/12/93 13:00	-0.55	-0.5096
27	02/12/93 13:30	-0.56	-0.513
28	02/12/93 14:00	-0.57	-0.513
29	02/12/93 14:30	-0.5887	-0.5089

Figure 12 Line series for the southern boundary

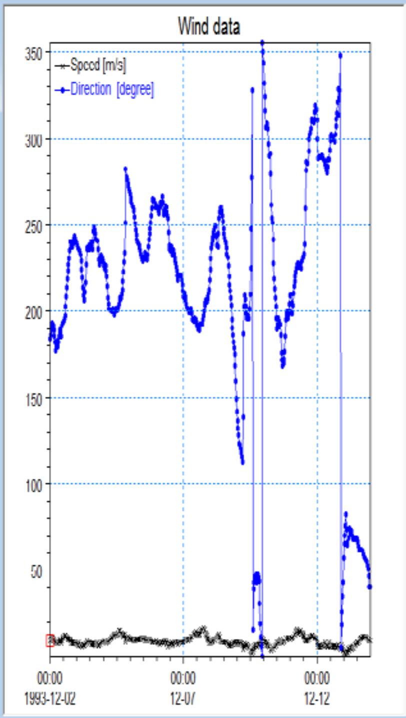
2.5.2 Initial conditions

The initial water level is calculated as an average between the level at the northern limit and the level at the southern limit, from the beginning of the simulation. The two boundary files will be added and an average level will be approximated from the beginning of the simulation. We will use – 0.37 m.

3 Wind forces

We will use the data from the measurements made in the Kastrup airport area to create a time series file that describes the wind forces and those that are constant in space. Insert the Time Series Editor and then choose the ASCII: *wind_kastrup.txt* file with the Equidistant Calendar Axis property. The *wind_kastrup.dfs0* file will be saved (Figure 13.). A wind speed and wind direction graphic will be obtained.

TS1 - Modified



	Time	1:Speed [m/s]	2:Direction [degree]
0	02-Dec-93 00:00:00	9.294	184.26
1	02-Dec-93 12:30:00 AM	10.066	186.689
2	02-Dec-93 1:00:00 AM	10.655	189.167
3	02-Dec-93 1:30:00 AM	11.22	191.531
4	02-Dec-93 2:00:00 AM	11.802	193.665
5	02-Dec-93 2:30:00 AM	11.202	193.254
6	02-Dec-93 3:00:00 AM	10.367	192.226
7	02-Dec-93 3:30:00 AM	9.659	189.522
8	02-Dec-93 4:00:00 AM	9.011	186.016
9	02-Dec-93 4:30:00 AM	8.401	181.983
10	02-Dec-93 5:00:00 AM	7.84	177.347
11	02-Dec-93 5:30:00 AM	8.314	179.364
12	02-Dec-93 6:00:00 AM	9.19	183.207
13	02-Dec-93 6:30:00 AM	8.995	182.151
14	02-Dec-93 7:00:00 AM	8.483	179.477
15	02-Dec-93 7:30:00 AM	8.509	181.976
16	02-Dec-93 8:00:00 AM	8.67	185.436
17	02-Dec-93 8:30:00 AM	9.89	188.395
18	02-Dec-93 9:00:00 AM	10.585	189.53
19	02-Dec-93 9:30:00 AM	9.539	187.74
20	02-Dec-93 10:00:00 AM	8.505	185.512
21	02-Dec-93 10:30:00 AM	9.86	191.843
22	02-Dec-93 11:00:00 AM	10.612	193.303
23	02-Dec-93 11:30:00 AM	11.106	193.637

Figure 13 Wind speed and wind direction from the Kastrup Airport area

We can obtain a broader presentation with the help of the compass rose. Choose Plot Composer – Insert new plot object – Wind/Current Rose Plot – and select the previously created file – *wind_kastrup.dfs0*. A compass rose will be obtained (Figure 14).

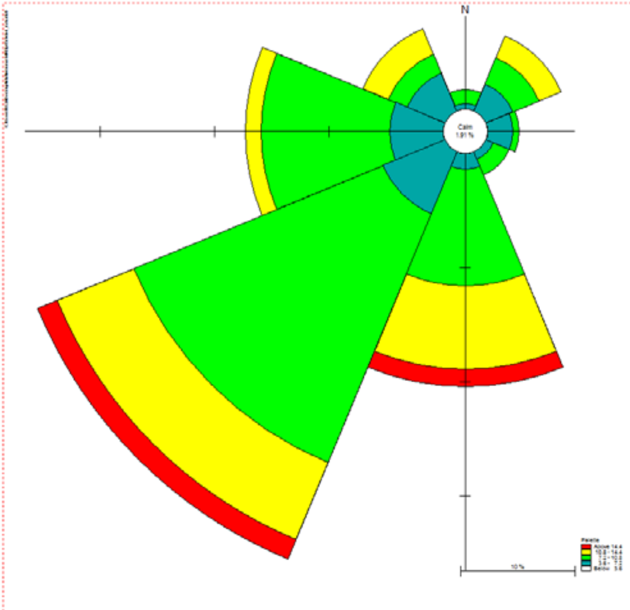


Figure 14 Compass rose

3.1 MIKE 21 simulation – Flow Model FM

3.1.1 Flow Model

Once the map has been created and the initial parameters have been set, the simulation process can begin.

The parameters from Table.1 will be used as input data to calibrate the model.

Table 1 Table with the initial parameters required for the calibration process of the simulation.

Parameters	File/Value
Specific file	Oresound.m21fm
Bathymetry and mesh	Oresound.mesh 5171 Nodes in the file
Simulation time	1993-12-02 00:00 – 1993-12-13 00:00 (11 days)
Time Step Interval	120 s
No. of time steps	7920
Technical solution and Final solution	Minimum request + fast algorithm Minimum time step: 0.01 s Maximum time step: 120 s

	Critical number CFL: 0.8
”Flood and dry”	”Drying depth„ 0.01m Flooding depth 0.05 m Wetting depth 0.1 m
Initial surface level	-0.37 m
Wind	Varies in time, constant on the domain: wind_kastrup.dfs0
Wind friction force	Varies with wind speed 0.001255 la 7 m/s 0.002425 la 25 m/s
Northern boundary	Waterlevel_north.dfs1
Southern boundary	Waterlevel_south.dfs1
Eddy Viscosity	Smagorinsky formula, constant 0.28
Resistance	The Manning number, constant value 32 $m^{1/3}/s$
Resulting files	Flow.dfsu ndr_roese.dfs0
Simulation time for CPU	25 minutes for a 2.4 GHz computer and 512 MB DDR RAM

To start the simulation, in the MIKE Zero start page, choose MIKE 21 – Flow Model FM (Figure 15).

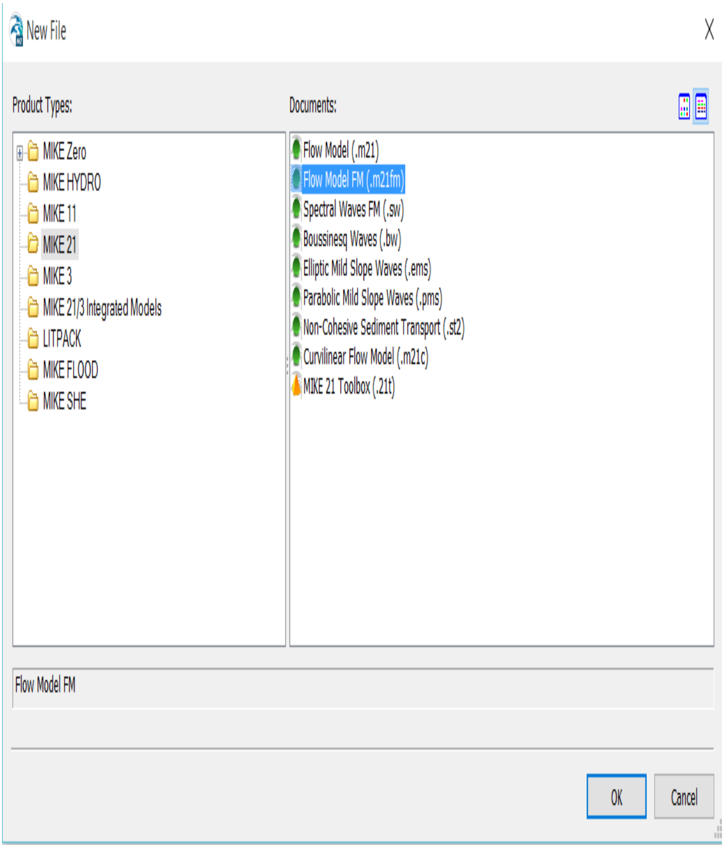


Figure 15 Choosing the simulation type

After choosing the simulation, a window will open in which the parameters to be filled in can be found in the right area (Figure 16).

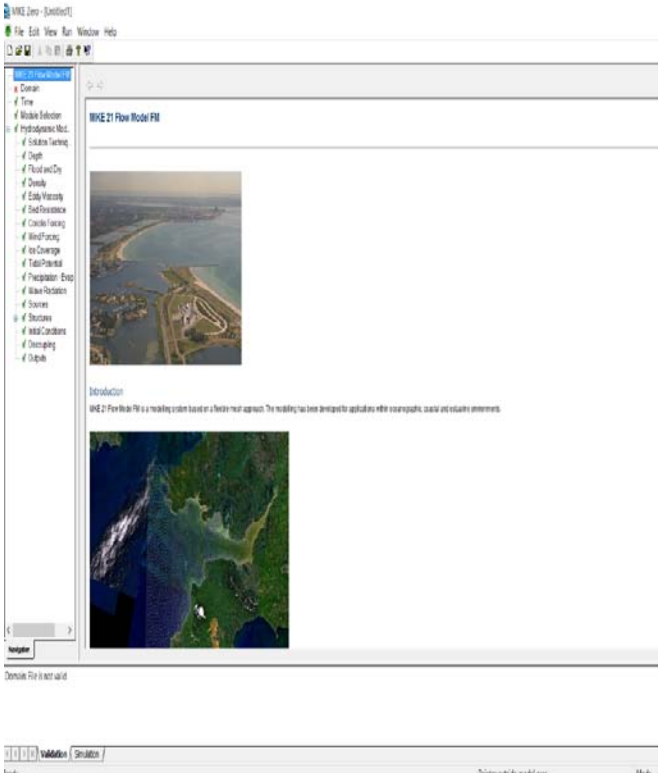


Figure 16 Mike 21 – *Flow Model*

Next, all the parameters necessary to start the simulation process will be added.

Domain: Specify the bathymetry and the created mesh, the oresound.mesh file and you will get a graphical view of the calculus network (Figure 17).

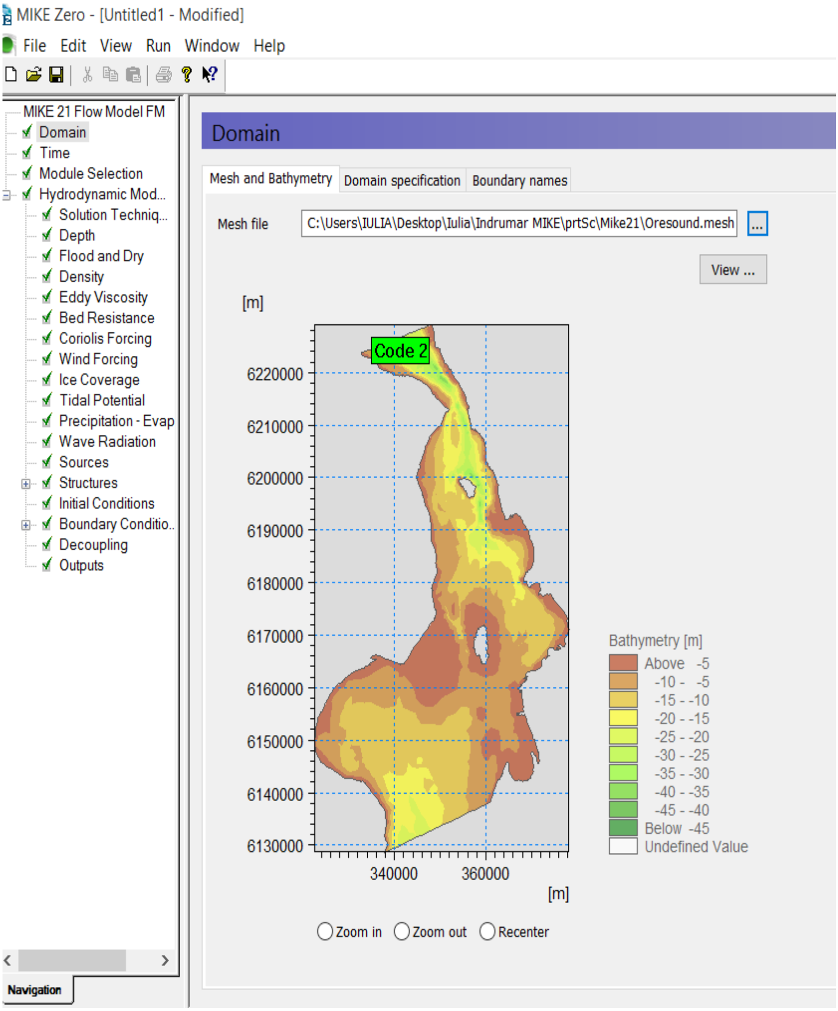


Figure 17 Graphic view of the oresound.mesh file

In the *Boundary Names* window, we will find the two codes attributed in the previous steps for the southern and northern boundary. Therefore, for the code 2 we will write *North*, and for the code 3 we will write *South*.

Time:

A time step of 120 seconds is specified. The time step interval must be specified for 7920 steps to simulate a total period of 11 days.

Module Selection:

Different modules can be included: Transport Module, ECO Laboratory Module, Particle Tracking and Sand Transport Module. For this application we will work with the Hydrodynamic Module which is automatically selected.

Technical Solution:

The minimum time step of [0.01s] and the maximum time step of [120s] is selected. The CFL critical number [0.8] is set to ensure the stability of the numerical system all throughout the simulation process.

Depth:

A spatial correction for depths can be used, however, it is nor necessary for this application because the bathymetry remains constant.

Flooded and dry areas:

In some areas, along the Saltholm coast, there will be dry areas during the simulation. If these areas are not taken into account, the model will not be able to operate in normal parameters during the simulation. These parameters can influence the stability of the model. However, in order to give up these parameters, it would be necessary to change the depth to prevent dry areas.

Density:

It will not be taken into account. Select "Barotropic".

Eddy Viscosity:

Choose Smagorinsky's formula with a coefficient of 0.28.

Resistance and Roughness:

We are working with the Manning number with a value of $32^{1/3}$ m/s, which will be used for the first calibration simulation. In the following simulations, this value can be changed.

Coriolis forces:

There are strong currents in Oresound but the effect of the Coriolis forces is not so significant, because the strait is quite narrow. However, Coriolis forces are always included in real simulations. Only in the laboratory can this type of force be given up. Therefore, we will select "*Varying in domain*".

Wind forces:

The file created in the previous steps will be used. For this, choose "*Varying in time, constant in domain*" and include the *wind_kastrup.dfs0* file. Fill in with 7200 for "*Soft start interval*" (the interval is a period from the beginning of a simulation in which the wind effect is not maximum). At the beginning of the interval the specified wind effect is forced to 0, after which it will increase till it reaches the maximum effect which will occur at the end of the interval.

Wind Friction:
Specify "Varying with Wind Speed" and use default values for this parameter.
Ice Coverage: is not included
Tidal Potential: is not included
Precipitation – Evaporation: is not included
Wave Radiation: is not included
Structures: is not included
Decoupling: is not included
Sources: is not included (there are no external sources in Oresound to influence the process)
Initial conditions:
After the boundary conditions have been established at the beginning of the simulation, the level of the initial surface is determined. For this example, we will use a constant level of -0.37m, which is the average between the southern boundary and the northern boundary from the beginning of the simulation.
Boundary Conditions:
Specify the name of the previously specified limits (in the *Domain* window). Choose the "Specified Level" water level type, because we have measurements about the water level. This level means that the water levels are forced to the limits, and the discharge at the shore crossing is unknown and will be estimated during the simulation. The boundary format must be set to "*Variable in time and along boundary*" to specify the boundary with the data files created in the previous steps, for North *waterlevel_north.dfs1*, and for South *waterlevel_south.dfs1*. In the *Soft Start* box, an interval of 7200 and a reference value corresponding to the initial value of -0.37m will be used.
Limit corrections for Coriolis forces ad wind force are omitted in this example because the special extension of the limit is relatively small.
Outputs – Area Series:
The name (flow.dfsu) and the location where the file obtained at the end of the simulation will be saved, will be specified. The resulting file size will be reduced to a reasonable size by changing the frequency (3600 is a reasonable frequency) depending on the time step (120s) as it follows: 3600s/120s = 30. In the following you will choose the parameters to be found in the resulting file: U speed, V speed, bathymetry, speed and direction of the currents, CFL number.
Outputs – Ndr. Roese)
The same changes from the previous step will be made for the Roese calibration station.

Now you can run the simulation: *Run – Start simulation*. The simulation is saved with the name: oresound.m21fm. If the simulation is not completed and errors occur, they can be seen in the white bottom window or in *File – Recent log file list.*

The resulting files can be viewed and analyzed using the *Plot Composer* tool in the main window for Mike Zero depending on the parameter chosen. (Figure 18, Figure 19, Figure 20, Figure 21).

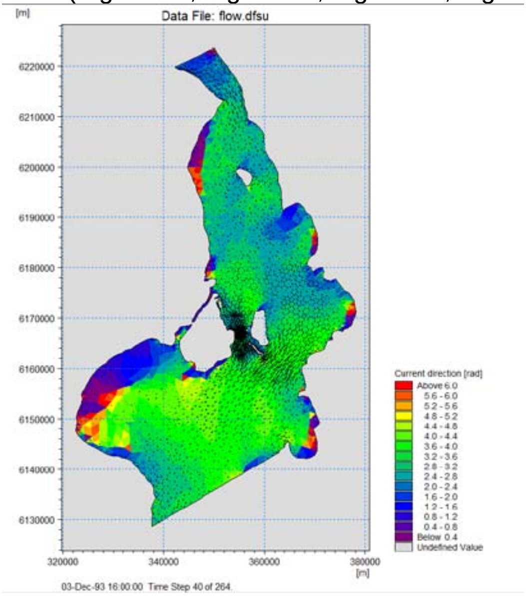


Figure 18 Direction of currents

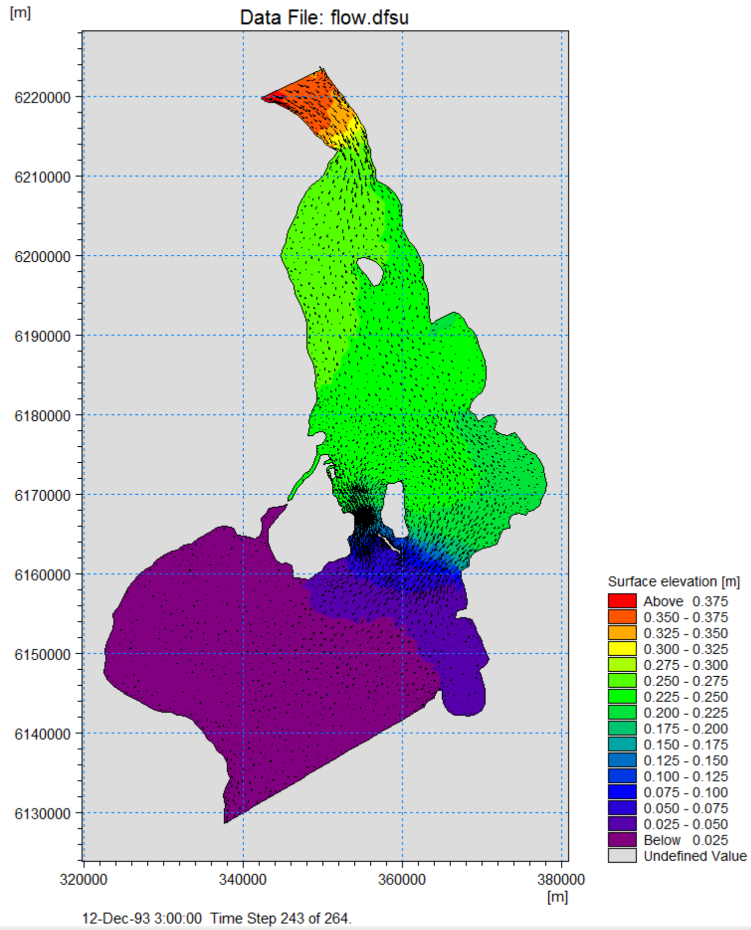


Figure 19 Altitude of the surface

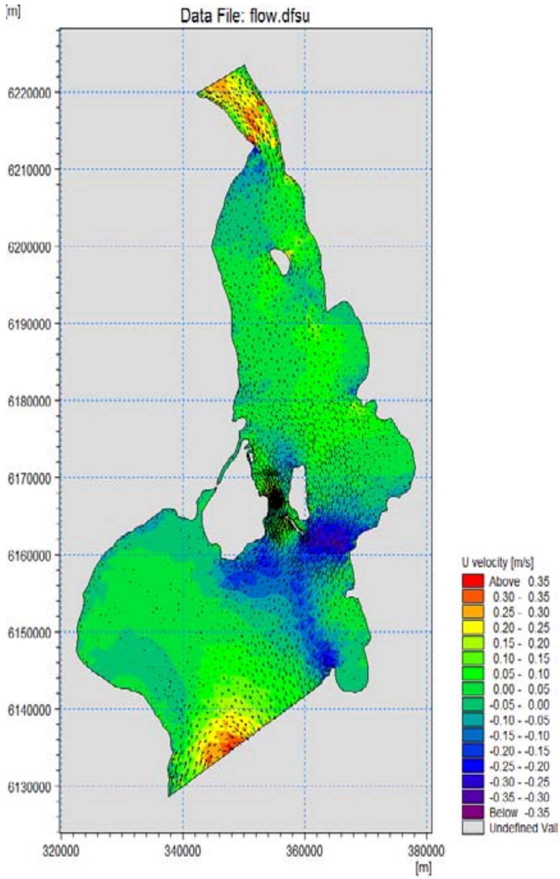


Figure 20. Speen in one direction

3.1.2 Model calibration

Some model measurements are required to calibrate the model. The measurements used are given by the water level and the speed of the currents.

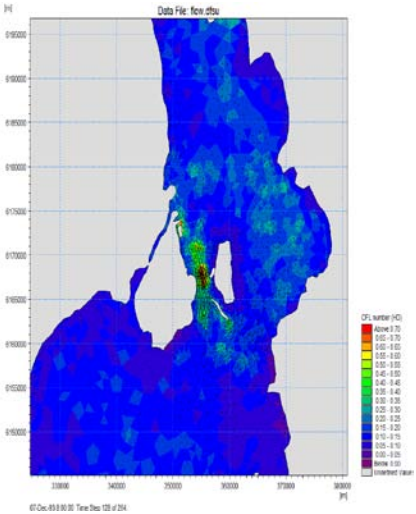


Figure 21 CFL number

3.1.2.1 Water level measurements

The measurements also come from the Ndr.Roese station (*current_ndr_roese.txt*). Import the ASCII file into the *Time Series Editor*. A series of data will appear for the current speed and direction, as in the Figure 22.

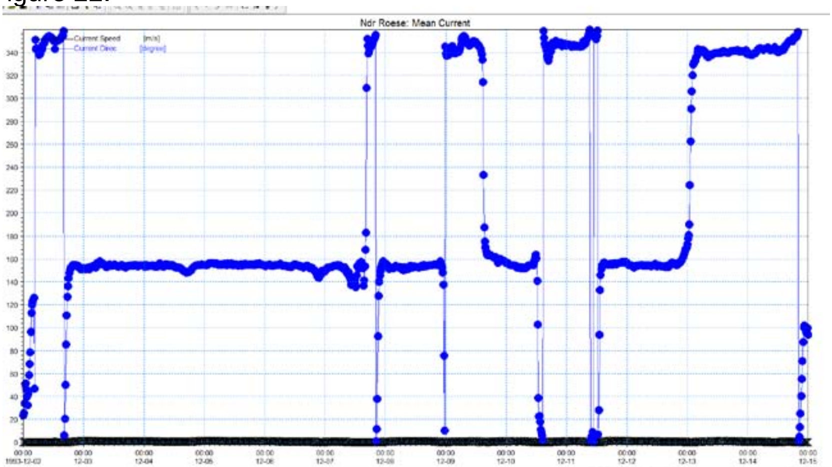


Figure 22 Ndr. Roese – Measurements for the direction and speed of the currents

3.1.3 Comparation between model results and measured values

Use *Plot Composer* to observe the differences between the two results. These comparations will highlight if the calibration improved the results and, if so, how much it did.

Try to change the Manning number to $45^{1/3}$ m/s and the value for Smagorinsky to $0.24^{1/3}$ m/s and simulate again. These two parameters can be decreased until the measurements become very close in value. (Figure 23).

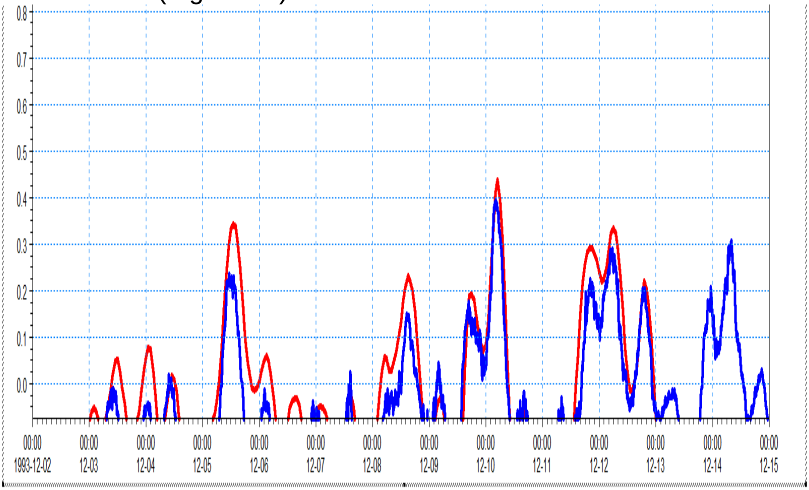


Figure 23 Comparation between the resulting file (in blue) and the file with data measured at the Ndr. Roese station (in red)

The resulting files will be closer in value to the real measurements.

5.10.2. REFERENCES

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2. Panaitescu M., Panaitescu F.V., Anton I,A., Advanced hydrodinamics. Monography, Nautica. Universitaria Publishing House Constanta, romania, 2019
3. https://www.mikepoweredbydhi.com/products/mike-eco-lab

4. https://manuals.mikepoweredbydhi.help/latest/General/MIKE_ECO_Lab_UserGuide.pdf

5. https://manuals.mikepoweredbydhi.help/latest/Coast_and_Sea/MIKE_FM_EL_Step_By_Step.pdf

Chapter 6

ENVIRONMENTAL COASTAL ENGINEERING APPLICATIONS. SOFTWARE. APPLICATIONS

6.1. Hydraulic and environmental engineering services for sustainable coastal development

“Coastal environments are transient – continuously reshaped by the natural forces of waves, tides, surges, erosion and deposition. To be sustainable, coastal development must be carried out with a clear understanding of — and respect for — these natural processes. Careful planning and comprehensive assessments are required to preserve the complex coastal dynamics and safeguard the coasts for future generations. A successful and long-lasting design of marine elements such as beaches and lagoons is only possible if the hydraulic, coastal and environmental aspects are included in the earliest planning stages” [1].

6.2. The challenges

- Reducing extensive investments involved in setting up coastal structures
- Limiting the environmental impacts of such structures
- Utilising the various aspects of a coastline to the maximum — for a given development project
- Integrating the possibilities offered by the marine environment with societal demands
- Contending with the vulnerability of coastal zones to the effects of climate change (such as sea level rise and more severe storms and surge)
- Predicting sediment transport and consequent morphological changes.”[1]

6.3. SOFTWARE, TOOLS

- waves: MIKE 21 Spectral Waves (SW), MIKE 21 Boussinesq Waves (BW)
- flow: MIKE 21/3
- cohesive sediment transport: MIKE FM Mud Transport (MT)
- non-cohesive sediment transport: MIKE FM Sand Transport (ST)
- littoral processes and coastline kinetics: LITPACK
- ecology: MIKE ECO Lab
- monitoring of waves, currents, water quality, marine biology bathymetric and sediment surveys
- shoreline stability and management
- sediment balances
- coastal protection and flood assessment
- optimising dredging projects
- feasibility studies
- Environmental Impact Assessments (EIAs) on projects and dredging activities

6.4. Applications

- **LONG-TERM SHORELINE PREDICTION**
- **FORECASTING THE IMPACTS OF COASTAL STRUCTURES ON COASTAL PROCESSES**

PREDICTING LONG-TERM SHORELINE MOVEMENTS – A VITAL NEED

Shoreline evolution can be natural or can be caused by the side effects of marine constructions, designed/artificial beaches and shoreline protection structures. Furthermore, climate change alters the base conditions under which coastlines evolve. In both cases, valid predictions of long-term shoreline movements are vital to mitigate or prepare for erosion and changes in coastal stability. Shoreline modelling addresses questions such as equilibrium shoreline, shoreline erosion and envelope (seasonal/event driven), sediment budget and so on. Our old 'working horse' shoreline model LITPACK (now known as Littoral Processes FM) is valid in cases where the coastline is open and fairly straight. However for other types of coastlines and for coastlines with coastal structures, an assumption of alongshore uniformity will not be valid. As such, a more detailed and robust method is required – one that can cater to long time scales and resolve gradients in the hydrodynamics along the shoreline at the same time. This is where our new sh

THE NEXT GENERATION SHORELINE MODEL

The new shoreline model introduces the concept of a 1-line model for shoreline evolution within the MIKE 21 FM framework (Figure 6.1). The shoreline model can be applied to problems over a longer time scale. This is due to the simplifications imposed on the morphologic evolution of the coastal profile, when compared with the existing twodimensional (2D) morphological model MIKE 21 Coupled FM. The shoreline evolution is based directly on the calculated sediment transport field from the area model MIKE 21 ST FM. The latter calculates the transport of non-cohesive sediments due to the action of waves and currents. Effects from coastal structures on shoreline evolution are inherently included in the new shoreline model because their effect on the waves and flow are included in the underlying models for wave transformation and hydrodynamics.

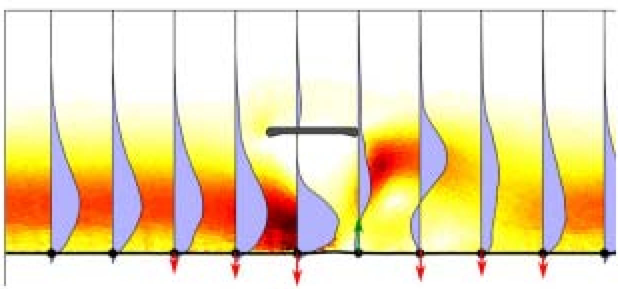


Figure 6.1. Shoreline evolution is based on a 2D sediment transport field. Changes in shoreline affects wave transformation, flow and the sediment transport. Source: Kristensen et al. (2013).

6.5. CASE STUDIES

"1. Nourishment at the Port of Dunkerque

In 2012, researchers investigated long-term shoreline evolution following different nourishment scenarios (nourishment on the beach, nourishment in the profile, how much and when to nourish and so on) at the French port of Dunkerque.

We used our new shoreline model for this purpose. The aim of the study was to improve protection of the dike (immediately east of the harbour) to increase safety against flooding of the hinterland.

The complex coastal processes in the area are caused by:

- a tidal range of 3.5-5.5 m
- drying of tidal banks located several kilometres offshore
- complex tidal driven transport in the tidal channels Several scenarios were investigated with 10 years of numerical shoreline modelling. The scenarios were compared by evaluating the remaining volume of nourished sediment. Regular maintenance nourishment was also considered in the study (Figure 6.2)(Source: Grunnet et. al. 2012).

Figure 6.2. Examination of beach nourishment at Dunkeque Port, France. Red colours indicate erosion. *Source: Grunnet et. al. 2012*

2. Shoreline management at Palm Beach

A number of different shoreline management schemes at Australia's Palm Beach were investigated by using the new shoreline model. The study compared three different protection strategies. During the work a, number of iterations were performed together with the customer in order to obtain the best solution for Palm Beach (Figure 6.3)(Source: DHI (2013). Photo: Google Earth).

Figure 6.3. Palm Beach. Illustration of management scheme with two headlands. View towards north.

6.6. FLEXIBILITY TO CHOOSE

The coastal profile included in the simulations may be specified by (Figure 6.4)[4]:

- a constant profile along the entire shoreline
- interpolation between a number of profiles
- direct extraction from a bathymetric survey The new shoreline model implements a flexible dynamic baseline, thereby allowing the model to be applied to problems with a curved coastline. CPU time spent on long-term shoreline evolution may be kept low by using the new quasi steady hydrodynamics formulation. In this formulation, we utilise a transition between real-time simulation of storms and simulations of more calm events where a speed up method for the calculations can be used.

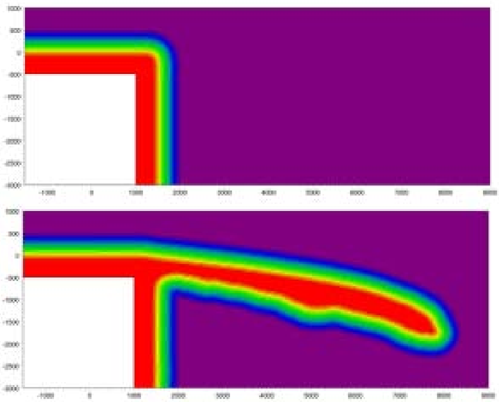


Figure 6.4. A dynamic baseline allows simulation of spit evolution in MIKE21 Hybrid FM. Source: Kaergaard (2013)[4].

6.7. BUILDING ON OUR VAST KNOWLEDGE OF COASTAL PROCESSES

The first of our numerical models for coastal processes were developed in the 1980s. These models were all based on generic descriptions of coastal processes founded on research carried forward by the Technical University of Denmark. Present day models continue along this path, relying on process-based descriptions. This allows for the application of the models to as wide a range of coastal types as possible."[5]

Other applications :
https://www.mikepoweredbydhi.com/products/mike-eco-lab
https://manuals.mikepoweredbydhi.help/latest/General/MIKE_ECO_Lab_UserGuide.pdf

https://manuals.mikepoweredbydhi.help/latest/Coast_and_Sea/MIKE_FM_EL_Step_By_Step.pdf

6.8. REFERENCES

1. https://www.dhigroup.com/areas-of-expertise/coast-and-marine/coastal-engineering
2. https://www.dhigroup.com
3. Nils Drønen - nkd@dhigroup.com
4. Kasper Kærgaard - kak@dhigroup.com
5. Sten E. Kristensen - skr@dhigroup.com

6.9. ***Practical class 6 .*** Intelligent specialization in the field of energy

“The S3P-Energy is a joint initiative of the Directorates-General for Regional and Urban Policy, Energy, and the Joint Research Centre (JRC). **The S3P-Energy is planned to become an enabling tool for regions to coordinate, rationalise and plan their respective energy strategies, develop a shared vision on knowledge-based energy policy development, and set up a strategic agenda of collaborative work.** The main objective of the S3P-Energy is to support the optimal and effective uptake of the Cohesion Policy funds for energy, and to better align energy innovation activities at national, local and regional level through the identification of the technologies and innovative solutions that support in the most cost-effective way the EU energy policy priorities. The S3P-Energy will contribute the EU energy policy priorities by facilitating partnerships between EU regions that have identified renewable energy technologies and innovative energy solutions as their smart specialisation priorities and by promoting alignment between local, regional, national and European activities on energy sustainability, competitiveness and security of supply.

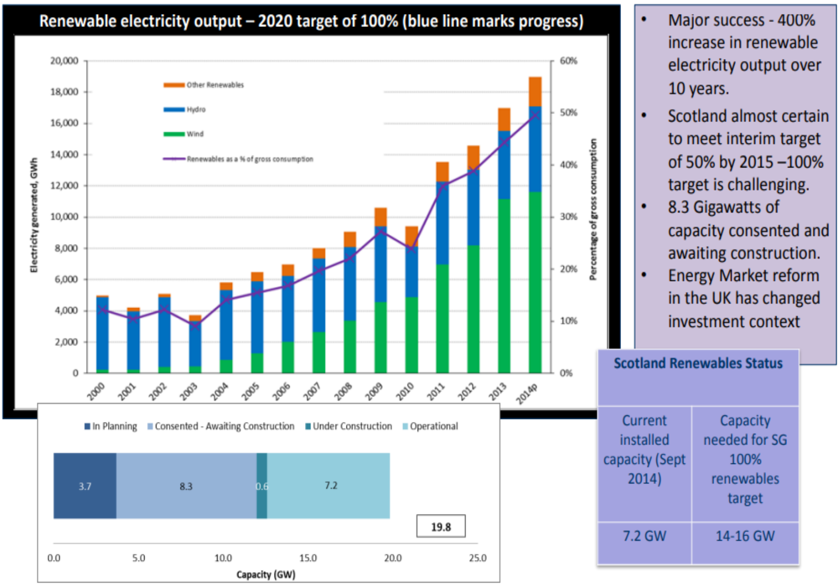
The S3P-Energy is addressing energy issues as part of the European efforts to achieve a shared vision on knowledge-based energy policy in regions and to encourage the financing of viable investments in Europe in line with the EU's Energy Union strategy and the EU Plan in strategic investments in jobs and growth, the latter to be realised through the European Fund for Strategic Investments (EFSI).

Numerous activities foreseen in the **EU's Energy Union five dimensions** including a fully-integrated internal energy market, supply security, energy efficiency, emissions' reduction and research and innovation in low-carbon technologies need to be put in practice at local

or regional level. Despite these activities rely on local potential they need to be also consistent with EU broad energy policy objectives; therefore the S3P-Energy will step-in to assure the developments in a coherent manner.
The ultimate objective of the S3P-Energy is **to contribute to the shift towards a low carbon economy by 2050** and to respond to some of the societal challenges identified in the EU 2020 Strategy. The EU has set out plans for a new climate and energy policy framework. Europe is determined to reduce its greenhouse gas emissions by 40 % by 2030 compared to 1990. Respectively, it has committed itself to achieve at least 27 % share of renewables. Hence, there is a clear link between innovation and the EU's energy and climate targets." [1]

Applications on [2], [3]

1. **Renewable Electricity Generation in Scotland**



The Challenges of Peripherality:

Planned island grid investment:

Scotland's island groups have huge untapped renewable energy potential (wind, wave and tidal), but are not currently connected to the National Grid

- Grid designed to transmit energy the other way - from population centres outwards
- Proposed island links are expensive
- Policy, market and regulatory barriers have prevented delivery of island links
- Charging methodology means higher charges for Scottish generation relative to rest of GB (further from demand)
- Significant recent progress:
  - Inter-governmental Delivery Forum
  - Process outlined to deliver 2020/21
- Needs state aid amendment allowing support for Remote Island Wind generation

Expertise in Harsh Offshore Environments:

Leading R&D in offshore renewables:

- **European Marine Energy Centre (EMEC)** is the world's only accredited testing facility for wave and tidal energy converters
- **Offshore Renewable Energy Catapult** based in Glasgow
- **FloWave** test tank in Edinburgh
- **SuperGen UK** Centre for Marine Energy Research
- The establishment of **Wave Energy Scotland in 2015**

Expertise:

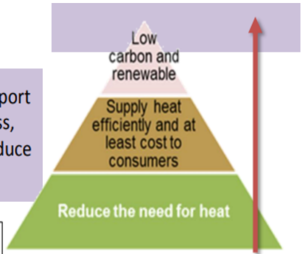
- International sales from Scotland's oil and gas supply chain grew to £11.2 billion in 2014, up 12% on the previous year. International activity now half of total oil and gas supply chain sales.

- UK has deployed largest offshore wind generating capacity in Europe.

VANGUARD INITIATIVE
New growth through smart specialisation

Scotland/Basque region pilot underway in the development and production of robust, high integrity equipment and components for applications related to marine renewables and energy and resource extraction in the most demanding marine environments.

Local Heat and Energy Efficiency:



Ambition: drive economic growth and competitiveness, and support efforts to tackle inequality, by enabling every household, business, public sector and third sector organisation to use less energy, reduce their fuel costs and cut their carbon emissions.

Heat vision:

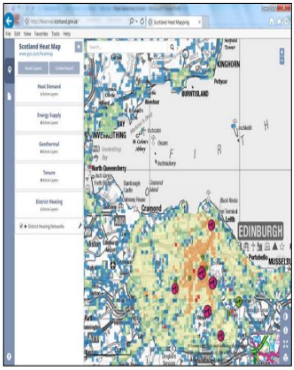
- a **commercially viable, diverse industry** delivering resource efficiency, low carbon and renewable heat to serve Scotland's heat needs

- a **largely decarbonised heat system** by 2050, with significant progress by 2030:

- Clear ambition for district heating
- Programmes supporting uptake of **Renewable Heat Incentive**
- Heat map: www.gov.scot/heatmap

Energy Efficiency:

- Scotland's energy consumption in 2012 was 11.8% lower than 05-07
- Established £76 million **Low Carbon Infrastructure Transition Programme –** Scotland-wide, cross-sector project development unit, supporting acceleration of low carbon infrastructure development.
- Created the **Resource Efficient Scotland** advice and support programme, supporting over 33,000 organisations to realise over £49 million and 910 GWh of lifetime energy savings



Carbon Capture and Storage at Peterhead:

First step: The world's first full-scale gas carbon capture and storage project - The Peterhead CCS Project.
This collaboration between Shell and SSE aims to capture **one million tonnes of CO_2 emissions every year** and transport it by pipeline 100km offshore for long-term storage deep (2.5km) under the North Sea via an existing oil pipeline.

Scotland ideally placed to realise CCS on a commercial scale:

- North Sea is the largest CO2 storage resource in Europe
- Existing oil & gas capabilities, ready supply chain and expertise, existing pipeline and platform infrastructure

Strategic ambition:

- Peterhead is one of two CCS demonstration projects in UK Government's £1bn CCS Commercialisation Competition, alongside White Rose in Yorkshire
- Also supporting Summit Power's Caledonia Clean Energy Project, a 570 MW CCS coal-gasification power station at Grangemouth
- Big steps towards building a "critical mass" which would allow:
  - ✓ Major contribution to future energy decarbonisation
  - ✓ Enhanced Oil Recovery, which offers a major new commercial opportunity for the UK Oil and Gas Industry

2. Energy Priorities of Regions and Needs for Support Launch of European Smart Specialisation Platform on energy

"The "Energy Union Package"[4]

Goal: "a resilient Energy Union with an ambitious climate policy at its core is to give EU consumers - households and businesses - secure, sustainable, competitive and affordable energy. Achieving this goal will require a fundamental transformation of Europe's energy system."
Ambition: "to make the EU the world number one in renewable energies"
Excursion: advantages of renewables

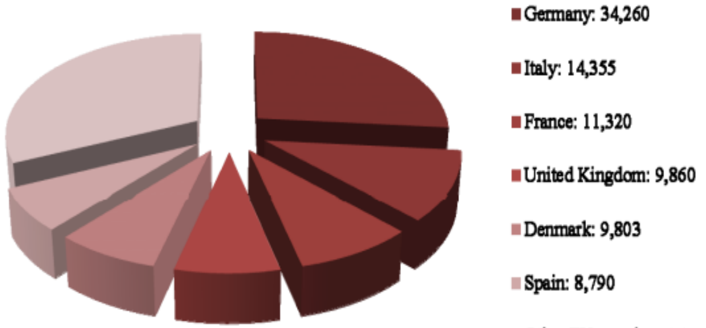
- Creation of local jobs and business opportunities
- Capacity building and community empowerment
- Contribution to regional economic growth and wealth
- Stable affordable energy prices
- Reduced/no energy dependence
- Cleaner environment causing reduced risks to public health and increased living conditions.

Renewable Energy Employment
In 2012, the year with the latest available complete dataset, there had been more than 1.2 million direct and indirect jobs in the renewable energy sector throughout the 27 EU Member States.

Turnover

- EU renewable energy industry generated nearly a € 130 billion turnover within 2012;
- Germany is by far at the top in terms of renewable energy induced turnover, with more than 26% of total EU turnover;

- o Italy and France passed the € 10 billion threshold;
- o The UK, Denmark and Spain got close to it.



Turnover of the renewable energy sector within the EU in 2012 (in millions of euros (€M)

Prerequisites to make the EU the world Nr.1 in Renewable Energies

- o Renewable energy and energy efficiency as centre piece of a new stable, secure, affordable and democratic EU energy system
- o Clear long-term commitment to 2050 EU goal and international commitments (investment security)
- o Decentralised energy system with polypoly of independent power producers
- o Innovation strategy coupled with a robust industrial policy to maintain or regain Europe's leading position in renewables
- o Stronger support to export opportunities and provision of solutions for developing countries
- o Develop plan to phase out fossil fuels and nuclear energy; no shale-gas development.

A new Energy Governance structure

1. Precise and robust governance system which
- Guarantees investment security
- Promotes cooperation and coordination among Member States
- Ensures achievement of 2030 RE target.
2. Defining national renewable energy contributions
3. Incentivizing national investments in renewable energy
4. Ensuring the implementation of national contributions 4 Regional cooperation and coordination.

A new Energy Market Design

- Promotion of increased flexibility (generation, consumption, storage)
- Enhanced European interconnectivity (transnational grid capacity)
- Creation of common balancing markets ¾ Guaranteed priority dispatch for all RES
- Democratic energy supply in European regions
- Increased interaction between relevant sectors (power, heating and cooling, transport).

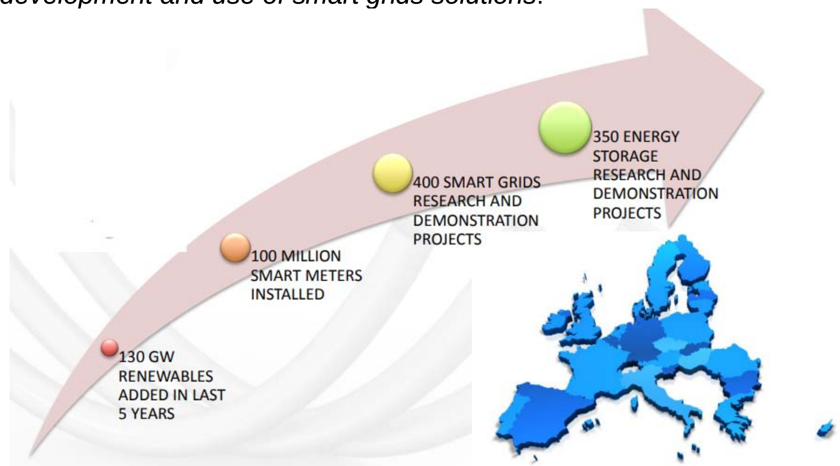
View of the Smart Grid Infrastructure Industry

SMART GRIDS INFRASTRUCTURES ARE THE BACKBONE OF THE INTEGRATED *ENERGY SYSTEM OF THE FUTURE*

SMART GRIDS ENABLE ALL PILLARS OF THE EUROPEAN ENERGY UNION:

• Security, solidarity, trust
• Competitiveness and the completion of the internal energy market
• Moderation of demand
• Low emissions in the EU energymix
• Research and innovation.

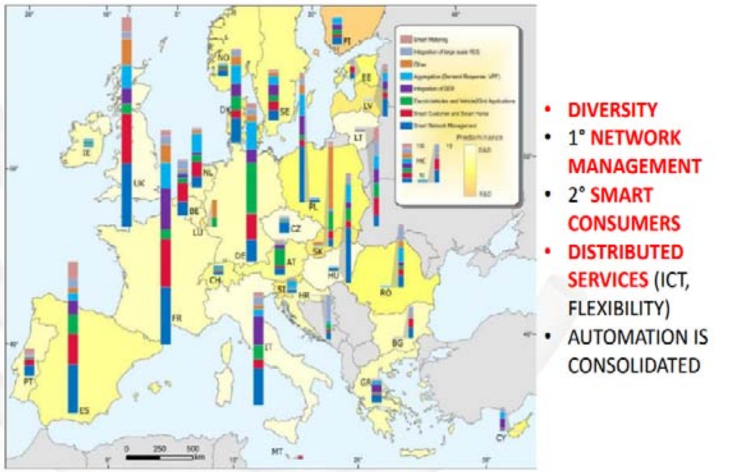
EUROPE has a recognised and consolidated world leadership in the development and use of smart grids solutions:

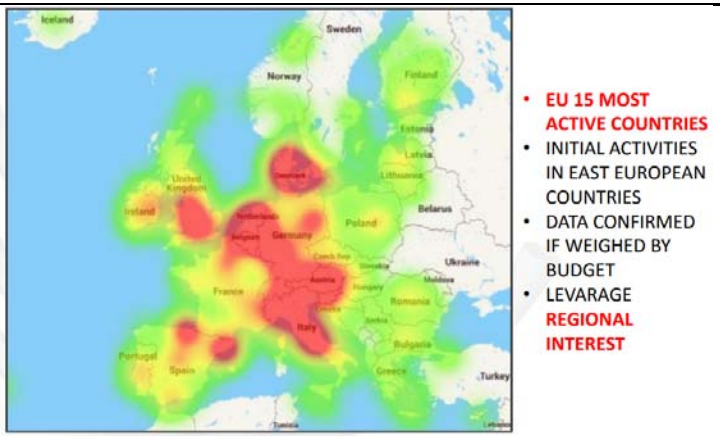


SMART GRIDS SECTORAL SPECIALISATION IN EUROPE:

• MOST OF THE MAJOR SMART GRIDS TECHNOLOGY PROVIDERS ARE OF EUROPEAN ORIGIN
• technologies are tested and deployed outside EUROPE
• RD&D plans and investments are attracting plants and excellence centres outside EUROPE

• EUROPEAN NETWORK OPERATORS HAVE ADAPTED THEIR SYSTEMS WITH A PROACTIVE ATTITUDE TOWARDS INNOVATION
• roadmap for implementation – 2022
• rolling implementation plans available 2016-2018
• need more data about national/regional projects
• EUROPEAN REGULATORS ARE AMONG THE MOST ACTIVE IN PROMOTING SMART SOLUTIONS
• third energy package promotes R&D activities by operators remunerated on the electricity bills smart grids sectoral specialisation in EUROPE
SMART GRIDS GEOGRAPHICAL SPECIALISATION IN EUROPE:





ACTIONS:

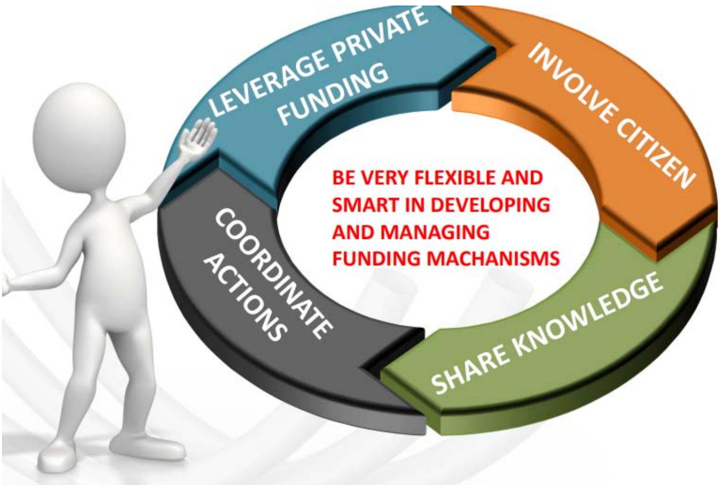
COORDINATE ACTIONS:

• COORDINATE FUNDINGS FROM EUMS-REGIONS ON COMMON GOALS

• UNLEASH THE POTENTIAL OF STRUCTURAL, COHESION AND RESEARCH FUNDS TO CONSOLIDATE EUROPEAN PREMIERSHIP BASED ON REAL EXPERIENCE (also through the PCI) – BE FLEXIBLE WITH PROCEDURES

• WORK WITH PROJECTS AND LOCAL PROGRAMMES TO OPTIMISE RESOURCES

• ATTRACT LESS ACTIVE COUNTRIES THROUGH EXAMPLES AND BUSINESS CASES



LEVERAGE PRIVATE FUNDING

• INVOLVE INDUSTRIAL STAKEHOLDERS IN DEVELOPMENT PLANS

• PROMOTE AND SUPPORT THE GLOBAL LEADERSHIP OF EUROPEAN TECHNOLOGY PROVIDERS

• MAKE POSITIVE BUSINESS CASES

• MOTIVATE STANDARDISATION AND INTEROPERABILITY

• WORK WITH REGIONAL CLUSTERS OF EXCELLENCE

SHARE KNOWLEDGE

• IMPLEMENT REPOSITORIES FOR SHARING KNOWLEDGE FROM ONGOING PROJECTS.

• CREATE COMMUNITIES OF PROJECTS TO EXCHANGE KNOWLEDGE AND BEST PRACTICES (thematic living documents)
• INVOLVE ACADEMIA IN A CONTINUOUS PROCESS OF SKILLS DEVELOPMENT AND UPDATE
• LEVERAGE PUBLIC RESEARCH CENTRES AND THEIR CAPABILITIES OF BRIDGING COMMUNITIES
INVOLVE CITIZEN
• CONSIDER THREE LAYERS PROJECTS: TECHNOLOGY-MARKET-PEOPLE
• DEVELOP CROSS-SECTORAL INVOLVEMENT METHODS
• LEVERAGE SOCIAL NETWORKS AND COMMUNITIES
• INVOLVE CITIZENS ALONG THE ENTIRE PROJECT CYCLE – VALUE ADDED
• MONITOR INVOLVEMENT IN THE LONG RANGE.
More:
https://ec.europa.eu/research-and-innovation/en/horizon-magazine/topics/energy?pk_campaign=search_campaign&pk_source=google&pk_medium=search

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6.11. *Lab 6.* Experimental Hydrodynamics and its Impact on Bathing Areas

- Modelling the Quality of Bathing Waters [8]
- Hydrodinamic quantum analogs [9]
- Physico-chemical hydrodinamics-interfacial phenomena [10]
- Dinamics of nonlinear waves [11]

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Chapter 7

ArcGIS-INTRODUCTION AND APPLICATIONS IN COASTAL ENGINEERING

7.1. Definitions

ArcGIS is a geographical information system (GIS) software. This software allows handling and analyzing geographic information by visualizing geographical statistics through layer building maps like climate data or trade flows. It's used by a whole host of academic institutions and departments, both in the humanities and sciences, to develop and illustrate groundbreaking research. Further, it is used by several governments and private/commercial institutions worldwide.

The system has the capacity to create geographical information, working as a platform whereby geographical information can be linked, shared and analyzed. The results helps to make decisions (Figure 7.1).

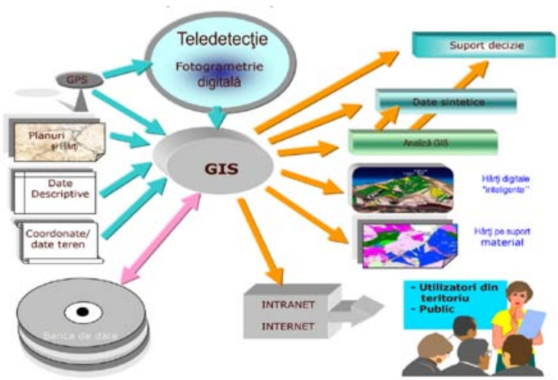


Figure 7.1. The way of making decision

7.1.1. About GIS

So...a GIS is made by 2 databases: a text database and a graphic database.

We can say that a GIS is an alive map. Why alive? Because what we find on the map we have to find in the land and what we find in the land must be reflected in the map.

To keep alive this system we have to ensure that any change in the land will be recorded in the system.

If we give a definition for GIS we can say that

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface.

GIS represents geographic data and map information as data layers. A GIS includes five basic components:

- Data
- Software and hardware
- Procedures and methodes
- Applications
- People – without this components a GIS cannot function.

A GIS is working with cartographic, photographic and digital data or tabular data (spreadsheets)

Cartographic data - obtained by topographic measurements and may include information about location (X and Y coordinates), relief (Z quota)

Photograhic data involves analyzing aerial photo. These photo can be spreaded on the map, keeping the real X and Y for the photo's corners.This operation is named georeferencing.

Digital data are data collected by satellites, as land use – forests, towns, villages etc.

Tabular data – we must create this database using a software as SQL Server or Oracle or other like these, but to make it we have to decide first the architecture of our database, what type of data we need, what type of queries we will make, what type of results we expect from. These tabular data must be georeferenced and after this process they will become geographic information.

Regardless of the internal organization, any true GIS must contain the following software components adapted to georeferenced data:

- data entry, editing, transformation, verification and validation system
- database management system
- image processing and analysis system
- computerized mapping system
- statistical and spatial analysis system
- display system

The use of GIS should not be understood as a simple interpretation of the results obtained by entering data in a set of pre-existing formulas. We know that each problem is unique, the most efficient way to use the resources of a GIS is to go through the following steps for each practical situation:

- defining the problem
- acquisition of the necessary data
- data processing and exploitation of all related information
- elaboration of spatial reports and spatial scenarios
- interpreting the results and proposing the optimal decisions.

7.1.2. GIS data and sources

GIS data is a combination of tabular and graphic data. We can use topograhic maps, aerial photography, satellite images, data of land surveys, reports, statistics reports and research publications. GIS can perform a lot of numerical analysis and statistical data on the data and it is useful in proper visualization of data to get cartographic output, charts and tables.

The most ordinary sources for spatial data are: point data from topographic measurement, aerial photographs, remotely-sensed images, hard copy maps as analogue maps, existing digital data files etc. The most popular data are analogue maps. To use this kind of maps we have to georeference them. Georeferencing is the process of converting an image into a file or page coordinates to a file in map coordinates, map projection and datum. So, all this information will made a database. To make a GIS we need 2 types of data: graphic data and attribute data. Any textual or tabular data can be referenced to a geographic feature – point/line/area. Attribute data will be insert in system by keying or import as ASCII format.

7.1.3. Attribute data for GIS

- We can find attribute data in a wider variety of data sources as: GIS Data from Libraries, Data from National Mapping Agency (ANCPI) and International Mapping Agencies, Municipal Data, Bathymetry data, georefecenced images, elevation data etc. In this way, any tabular or textual data would be referenced to a geographic feature (a geographic feature is type point, or type line or area).
- Attribute data is ASCII format and is usually input by manual keying or import database.

Graphic data can be obtained from topo maps, aerial photographs, satellite images, hard copy maps etc. Satellite image is a raster dataset coordinates file (rows and columns) that have to be converted to map coordinates. Aerial photography sometimes comes into GIS as georeferenced data. Hardcopy map will be used as a backdrop for georeferencing. In the system these data will be inserted as points or lines or areas.

Acquiring geographic data is an important factor in any GIS.

Procedures of data Input (data entry is the operation of encoding both types of data into GIS database formats)

- data capture and manual/automatic map digitization - manual digitizing: digitization is the operation of creating GIS data using analogue data or paper. This process, called georeferencing,

involves registering of raster image using known coordinates or ground control points. At the end of digitization we have different types of features: point, lines or areas.
- automatic scanning
- entry of coordinates
- conversion of existing digital data

To insert photographies and analogue maps into a GIS database we have to know what means georeferencing process. A georeferencing process is the process of converting an image in file/page coordinates to a file in coordinate system. For example, a scanned map is a raster file which have to become a vector file. We see the coordinates written on the scanned map. We will georeference the raster file and get vector data by spreading the raster map between the coordinates written on the map.

7.1.4. Assure topology

GIS contains tools for creating topological relationships between features withind and between datasets. If we have to digitize an analogue map we create digitizing features and the next step ist o assing an ID value to each feature that has been digitized. This ID represents the unique identifier for each feature.

7.1.5. Maps for different type of information – Examples

- Figure 7.2- The depth of the Black Sea
- Figure 7.3. The Black Sea Map
- Figure 7.4. Surface circulation in the Black Sea
- Figure 7.5. Black Sea water salinity Map
- Figure 7.6. Temperature of Black Sea

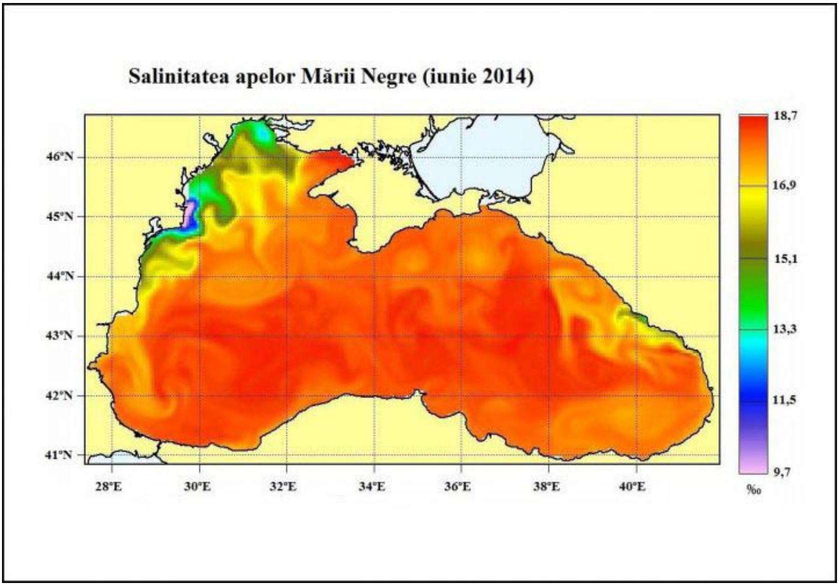


Figure 7.2. The depth of the Black Sea

The average depth of the Black Sea is 1,271 m. The maximum depth reaches 2,212 m (towards the central-southern part, at a point located 111 km from the southern shore, on the line between Cape Chersones (Ukraine) and Cape Kerempe (Turkey); near Yalta 2,206 m.

Within the structure of the submarine relief of the Black Sea, there are four distinct areas, distributed relatively unevenly:

- the shelf (continental shelf),
- the slope (steep),
- the piedmont (deep basin)
- the abyssal plain.

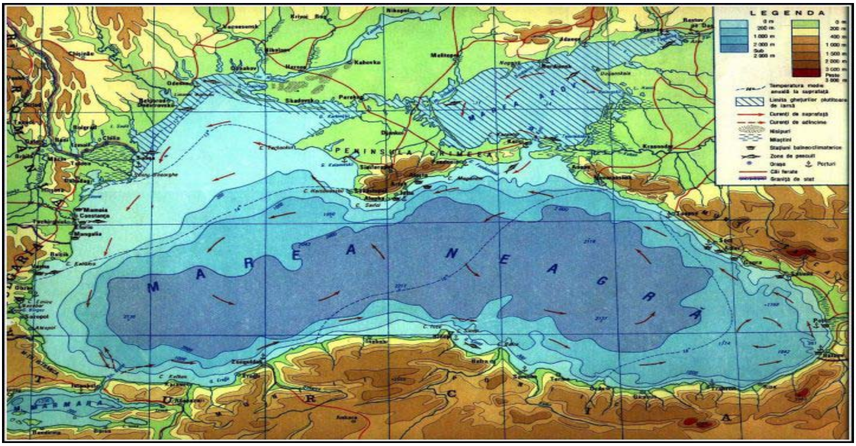


Figure 7.3. The Black Sea Map

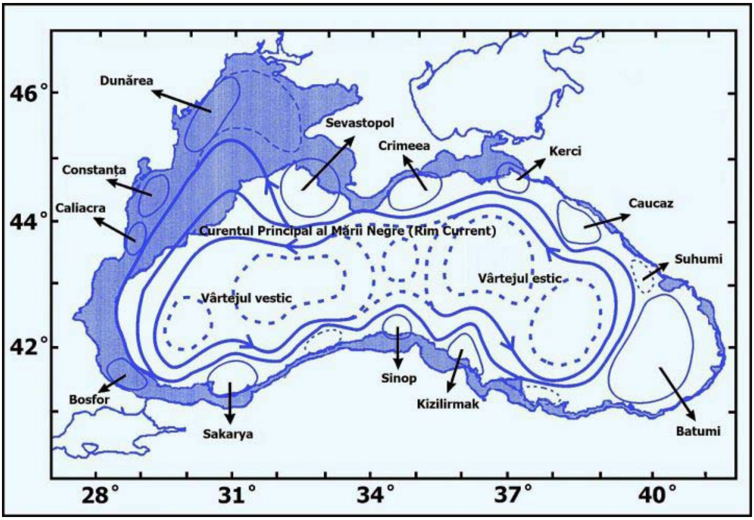


Figure 7.4. Surface circulation in the Black Sea

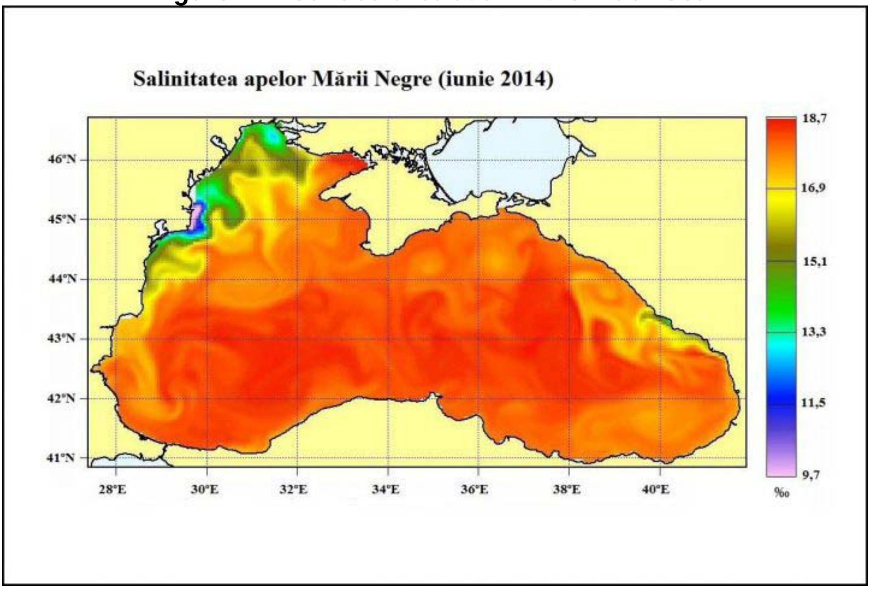
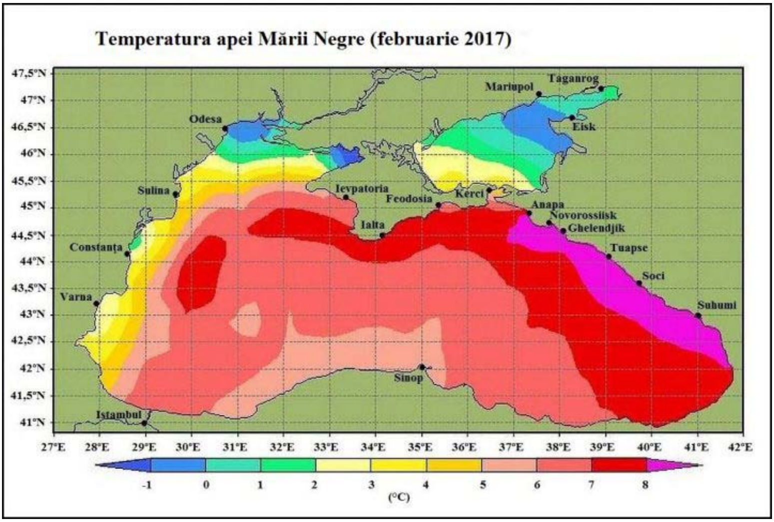


Figure 7.5. Black Sea water salinity Map-



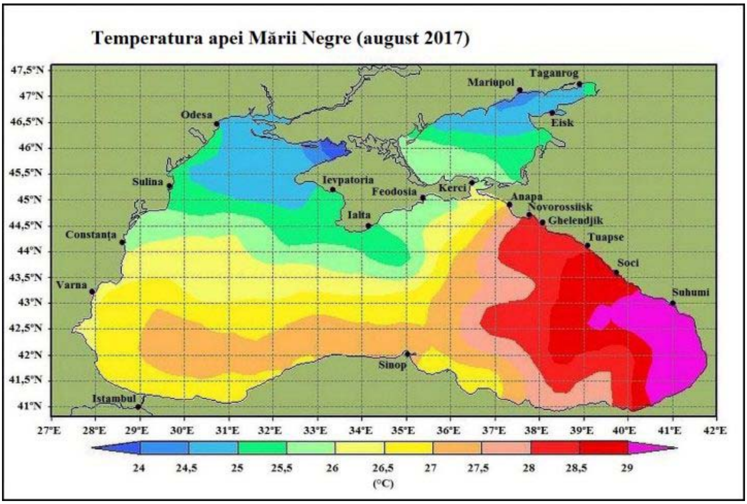


Figure 7.6. Temperature of Black Sea

7.2. Coastal Area

7.2.1. Definition of Coastal Area

A coastal is a zone where the land meets the sea. This zone can't be clearly defined, so its width can be extended inland from the sea and the shores are influenced by the wave process, by the presence of bays, lakes, marine currents etc. All attribute-data about coastal zone will make a text database. When we say all data we refer to engineering disciplines as environmental sciences, geology, marine science, hydrology, physics, mathematics, statistics, hydraulics, structural dynamics etc.

To study the *Coastal Area* the coastal engineer must consider that kind of process present in the area of interest:

- Chemical and ecological processes = environmental processes
- Hydrodynamics processes = waves, currents, winds, water level fluctuations
- Seasonal meteorological trends – storms
- Sediment processes – characteristics, sources
- Geological processes
- Long-term environmental trends
- Social and political trends and conditions – land use, development, economics etc

Below, will be presented a beach profile and its terminologies(Figure 7.7, Figure 7.8)[1]

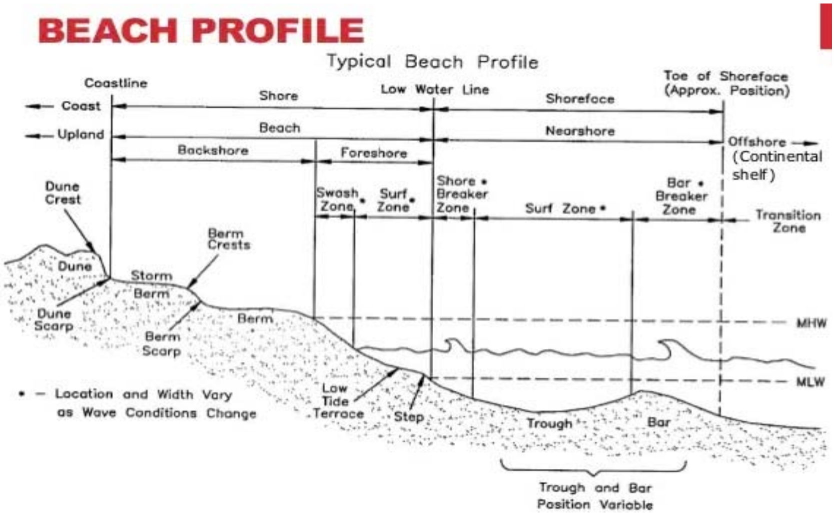


Figure 7.7[1]. Typical beach profile

Figure 7.8. The beach and the nearshore [1]

[1] Dr.Mohsin Siddique – Coastal Eng.

7.3. ARCGIS PRESENTATION

7.3.1. Geographic computer systems

Geographical Information System (GIS) is a working technique increasingly used in the contemporary world, both in the field of theoretical research and in many practical activities [1]. As a structure, GIS has information components related to geographical coordinates. Components are introduced, stored, handled and analyzed using a computer. The end of a GIS analysis consists in displaying the complex information spatially correlated to the real geographical coordinates with the possibility of performing more complex analyzes, practically impossible to perform with classical techniques. GIS allows the combination of different information (maps, figures, images, etc.), hardware and software components, coordinates and the human component [2].
GIS techniques are used for two reasons [2]:
- allow to solve objectives more precisely, and are more complex than classical techniques;
- there is no other practical way to achieve these goals.

7.3.2. ArcGIS software packages

ArcGIS is a software package produced by ESRI that allows the creation, processing, integration of analysis and display of geographic data at various levels [3]. Within the ArcGIS architecture (Figure 7.9)[3] users can access "ArcGIS clients" (ArcView, ArcEditor, ArcInfo) or "servers" (ArcSDE, ArcGIS server and ArcIMS). ArcGIS Desktop provides access to different "clients" if the data is local [3].

7.3.2.1. ArcGIS platform

The ArcGIS platform is a family of software products that form a complete GIS. It is built using industry standards, provides exceptional capabilities and is also easy to use. This version is characterized by a common architecture, common code, common extension model and a single development environment for ArcView and ArcInfo.

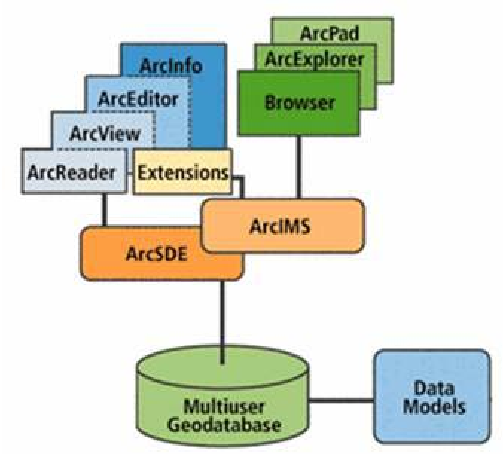


Figure 7.9. ArcGIS software package architecture [3]

The ArcGIS platform is built from desktop products and application services. Desktop products are (Figure 7.10) [3]:

• ArcView,
• ArcEditor and
• ArcInfo.

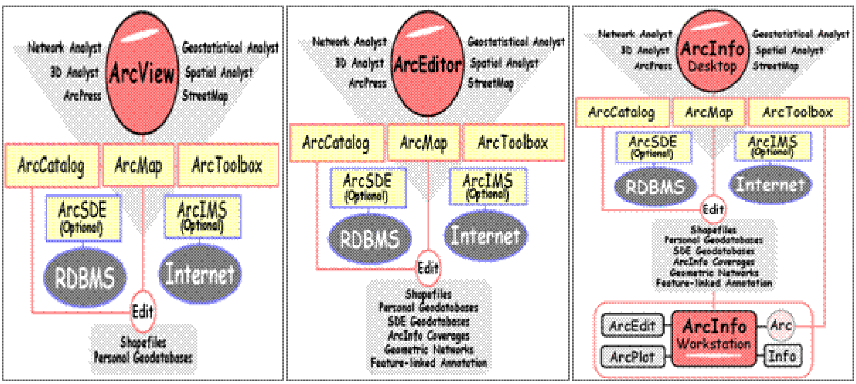


Figure 7.10. ArcGIS Desktop Components [3]

Application services are represented by:

• ArcSDE and
• ArcIMS.

Desktop products have as extensions:

- Spatial Analyst,
- 3D Analyst,
- Geostatistical Analyst,
- MrSID Encoder,
- ArcPress and
- StreetMap.

Also, Desktop products are all made up of the same applications:

- ArcCatalog,
- ArcMap and
- ArcToolbox.

ArcMap is the main application of the ArcGIS Desktop. It can be used for integrating data and visualization, creating or updating both spatial data and attributes, building maps, performing analyzes.

ArcCatalog helps you organize and manage all your GIS data. ArcCatalog contains tools for exploring and finding geographic information, for recording and viewing metadata, for quickly viewing spatial data, and for defining the layout of geographic layers.

ArcToolbox is an application that aims to simplify GIS tasks through tools or wizards. ArcToolbox contains many tools for geo-processing. There are two versions of ArcToolbox:

- a full version that comes with ArcInfo and
- a simplified version for ArcEditor and ArcView.

With the tools in ArcToolbox you can perform data analysis and conversion, as well as their administration.

ArcView (8.x, 9.x), ArcInfo (8.x, 9.x) and ArcEditor (8.x, 9.x) have a common interface that together with the common architecture makes ArcGIS and geographic information accessible a variety of users with different GIS needs. The common architecture also allows users to share the same scripts, custom tools, applications, or extensions.

1.2.1.1. ArcView

ArcView 8.x is the most significant version in the history of this product. ESRI has built ArcView on a completely new architecture and user environment, based on current information technology standards. ArcView 8.x features an intuitive Windows user interface. It includes Visual Basic for Applications for creating programs.

ArcView 8.x maintains the basic functionality of ArcView 3.x and has added a lot of improvements as a result of user requests.

ArcView 8.x is an exceptional stand-alone product and is the entry point into ArcGIS. ArcView 8.1 consists of the same Desktop products: ArcCatalog, ArcMap and ArcToolbox.

The newest and most important features of ArcView 8.1 are:

• a new architecture that can be extended. The new architecture is designed specifically for Windows;
• improved mapping;
• instantaneous projections (projection-on-the-fly);
• increased editing;
• better administration of labels;
• Internet access.

ArcView reads all types of data (shapefile, coverage, geodatabase), but can edit only simple data models: simple shapefiles and personal geodatabase.
There are methods to import projects from ArcView 3.x to AcView 8.x.
ArcView 8.x can only be installed on Windows NT 4, Windows 2000 or Windows XP systems.
ArcView 9.x is a GIS component that allows viewing, querying, analyzing and creating maps. Provides tools for exploring, selecting, editing, displaying, analyzing, symbolizing, and classifying data, as well as for updating metadata.

7.3.2.2. ArcEditor

ArcEditor extends the functionality of ArcView. This product provides full support for data modeling, both for editing and designing a geodatabase.
ArcEditor is a new key product that extends ArcView's capabilities to complex data editing. Several users can edit the same database at the same time if the ArcSDE extension is used.
In ArcCatalog, ArcEditor allows the administration of all data types from shapefile, coverage to SDE Geodatabase, the latter, only if there is the ArcSDE extension. It is also possible to create or modify the schema of various data types in ArcCatalog. In ArcMap, ArcEditor displays and edits all data types.
ArcEditor 9.x is an ArcGIS intermediate application that offers more features than ArcView, but less than ArcInfo. As the name suggests, ArcEditor also contains important functions for editing "coverage" and "geodatabase" entities.

7.3.2.3. ArcInfo

ArcInfo expands ArcView and ArcEditor. What brings ArcInfo new to ArcEditor is the full version of the ArcToolbox application. Thus, in ArcInfo all types of geo-processing can be performed, there are specialized GIS tools and support for the UNIX operating system is provided.

ArcInfo contains two modules:

• ArcInfo Desktop and

• ArcInfo Workstation.

The new features of ArcInfo 8.x are:

• the possibility to store raster data in a geospatial database;

• supports 3D coordinates and linear measurements;

• allows the realization of geocodings;

• allows Internet access;

• improved management of tabular data.

With ArcInfo all types of data can be displayed and edited, including SDE Geodatabase (if the ArcSDE extension exists).

ArcInfo 9.x is the most complex component of ArcGIS. In addition to the display and query functions included by ArcView and the editing functions included by ArcEditor, ArcInfo offers geoprocessing and data conversion functions, which are necessary to create complete GIS solutions.

All three of these versions include the ArcCatalog, ArcMap applications (each application including its own ArcToolbox application).

7.3.3. Start work session

• The operating system used is Windows XP;

• Your account is "Student" - no password;

• To open the ArcCatalog application:

- Click **Start->All Programs->ArcGIS->ArcCatalog** or
- Click **icon in ArcCatalog** from desktop (if exists).
- To open **ArcMap** application:
- Click **Start->All Programs->ArcGIS->ArcMap** or
- Click icon **ArcMap** from desktop (if exists).

7.3.4. ArcCatalog interface

ArcCatalog is a tool used to view directory and file structures and to organize GIS data. (Figure 7.11)[3]

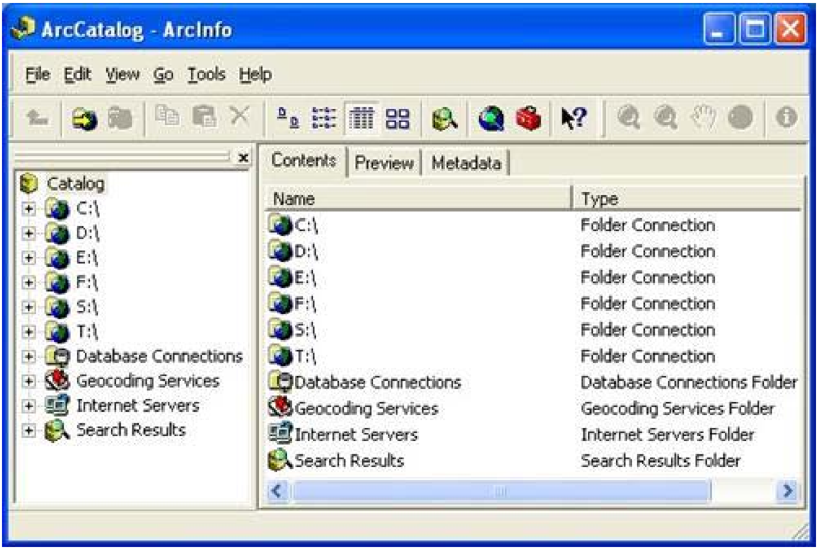


Figure 7.11. ArcCatalog-view objects in window [3]

The catalog (as a tree) in the left window is used for viewing and organizing directory and file structures. The selected objects on the left are displayed in the right side window. Contents, Preview and Metadata buttons (shown in detail below) are used to view more information about objects in the Catalog tree [3].
ArcCatalog shows the current list of drives and directories on your computer. The application works similarly to Windows Explorer.
Click D: create a new directory with the name of the subgroup "Grupa_82xxx"; in the new directory create another directory "Work_Lab1".
Browse the file structure and navigate to the C: arcgisArcTutorCatalog directory. Copy the Yellowstone directory to directory D: Group82xxxLab1_Work.

7.3.4.1. Connection to source data (working directory)

ArcCatalog allows you to set the path of data sources, allowing quick access to the directory in which you work and to the files in that directory.
Identify the button in the top bar. Click this button to create a connection following the path

D: Group82xxxLab1_work.
Access the direct connection D: Group82xxxWork_Lab1; browse the list of structures and files in the Yellowstone directory. select the Content and Preview buttons for each file; notice the file types and the particularities of each type.
Select the Metadata button; this button open a window that shows a data set spatial information; if select Space button it will be displayed , information about the projection system, the coordinate system, and by selecting the Attributes button, all the attributes associated with the selected object class are showed.
In ArcCatalog tree, select D: Group82xxxLaby_work1Yellowstone / states / polygon.
Select the Preview button and from the Preview dropdown list at the bottom of the page, choose Preview-Table. The contents of the table associated with the states-polygon dataset are displayed. The total number of records is displayed at the bottom of the window. By selecting a field from the tables and then right-clicking you can select procedures for sorting the recorded values, performing a simple statistic or setting the properties of that field (Freeze / Unfreeze).

7.3.4.2. Zoom, Pan and Identity tools

ArcCatalog allows you to browse geographic data to identify detailed information selected from table attributes and create thumbnails on geographic data.
The icon to Identify in the menu in the ArcCatalog application (Figure 7. 12)[3].

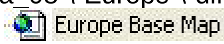
Figure 7.12. identification tool [3]

If you can't find this icon, you can activate it from View-> Toolbars-> Geography menu. The first two tools can enlarge or reduce the image.

The third tool,  Pan, can be used to move the displayed data. The button  can be used to create query from inserted data. The last menu button  creates thumbnails on the geographic data, meaning

it creates a small image of the geographic data that is displayed in the Content menu.
Select in ArcCatalog D: \ Group82xxx \ Work_Lab1 \ Yellowstone \ yellowstone.mdb \ roads.
Click Preview - Geography button. Practice these steps using Zoom in, Zoom out, Pan, Identify and Thumbnails buttons on the road object class.

7.3.5. ArcMap interface

ArcMap is the main application for:
• Exploration source data (geographical and non-geographical)
•Data analysis;
• Displaying results;
• Customizing the interface;
• Presentation of results
To open the ArcMap application:
Click Start -> All Programs -> ArcGIS -> ArcMap or in ArcCatalog from the ArcMap Launch button. 
In ArcCatalog, select D: \ Data_08 \ Europe \ directory and move the map-file Europe Base Map.mxd 

to ArcMap. A multi-layered map document is opened in ArcMap. The list of thematic layers is displayed in the left window, the geographical data is displayed on the right.
Save the map file to directory D: \ Group82xxx \ Work_Lab1 named Europa.mxd
ArcMap Features:

- ArcMap includes the Zoom in, Zoom out, Pan, Select Elements and Identify toolbars, as ArcCatalog.
- ArcMap has two options to display: Data View and Layout View (at the bottom of the right window, Figure 7.13) [3].
- Data View is used for viewing, querying and manipulating data, while Layout View is used for printing.
- ArcMap organizes data sets into Data frames. Each Data frame contains data sets shape files, grids, coverages or geodatabase. To ensure the connection between these databases, the data sets must be defined in the same coordinate system. If one of the datasets does not have a coordinate system defined, then a warning message appears and the coordinate system of the first loaded set is used.

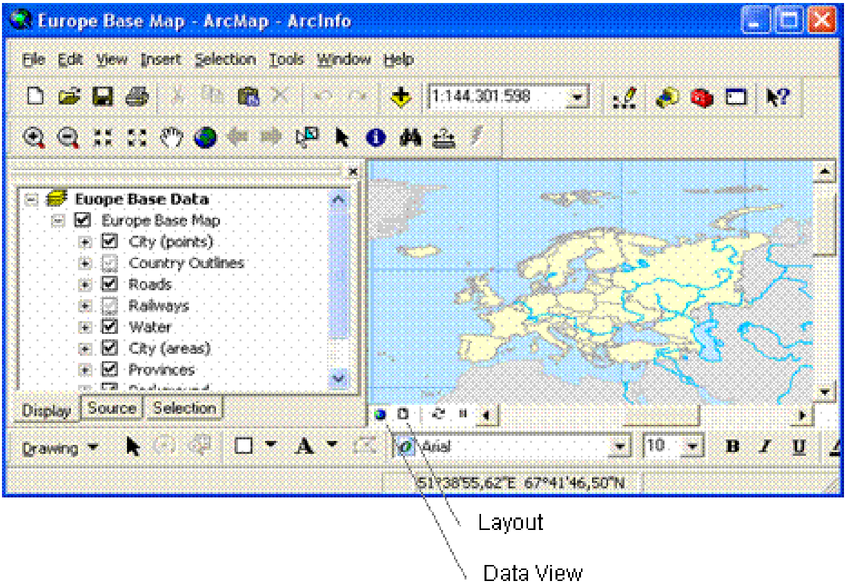


Figure 7.13. ArcMap application window [3]

ArcMap works with map documents with the extension * .mxd. Any added data set will be saved in the mxd file.

A geographic data set is a GIS "layer" in ArcGIS Desktop. A layer includes a set of particular data, included in a single spatial model (it can contain a single data type, for example a point type).

There are two main types of data representation in ArcGIS Desktop:

• Feature data - vector data;

• Image Date - raster data.

Layers can be added and deleted from a map, without affecting the data in that layer. Deleting a layer from ArcMap doesn't mean deleting the layer file from your hard disk.

- **The order of layers**

In ArcMap, Table of Contents window contains the list of layers in the order in which they were added and in the order in which they are displayed.

• Click "check box" of the Water layer. Notice what is happening.

• Select Zoom out on the surface of Romania;

• Change the order of the layers (by selecting with the left button, drag and drop when the black bar appears) and observe what happens;

Rearrange the layers in the order: City (points), Country Outlines, Roads, Railways, Water, City (areas), Provinces and Background.

- **Symbolization in ArcMap**

ArcMap allows you to assign a representation mode for each layer.
Change how layers are represented by selecting the symbol displayed next to the layer name. It will open a window in which you can select the type of symbol, color, size, etc.

- **Data Frame Properties**

Layers are organized in data frames. A data frame contains data sets that relate to a project, area, or topic. When you open ArcMap, is created a default Data frame called Layers (default / default layer). Data frame name can be changed:
• Double-click on the name and change or
• Right click on the name, select the Properties option - General button and change the name in the Name box.

- **Layout View**

Layout view allows you to design the map for printing and add additional information (title, scale, caption, other comments, etc.).
• Select View-> Layout View from the top menu or the page button at the bottom of the right window;
• Select Zoom out on the surface of Romania and set the scale to 1: 4,500,000;
• Set page / print options in File-> Page Setup: A4 size (8.5 x 11), Landscape;
• From the Insert menu, select the options Title, Legend, North Arrow, Scale Bar to enter the title, legend, etc.

- **Save the map file**

Select FILE-> SAVE AS and save the map file in directory
D: \ Group82xxx \ Work_Lab1 \ named lab1.mxd;
Click File-> Exit from ArcCatalog and ArcMap.

7.3.6. Data structures

The main questions are "What is GIS?" and "How does GIS work?" [4]. Geographic Information Systems (GIS) technology can be used to conduct scientific investigations, to plan and manage resources. GIS is a hardware and software combination. GIS includes processes, data and human resource. GIS supports the acquisition, management, analysis and visualization of spatial data (Figure 7.14)[6]. With GIS, public and private sector applications can be solved [5].
A GIS stores information about the world as a collection of features that can be linked by their geographical location. This extremely simple but versatile concept has proved to be of great value in solving many real world problems [5].

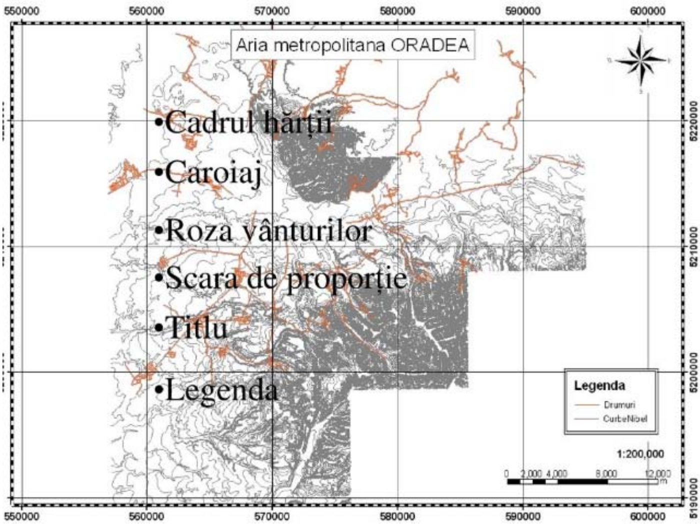


Figure 7.14. How GIS works by geographic location [6]

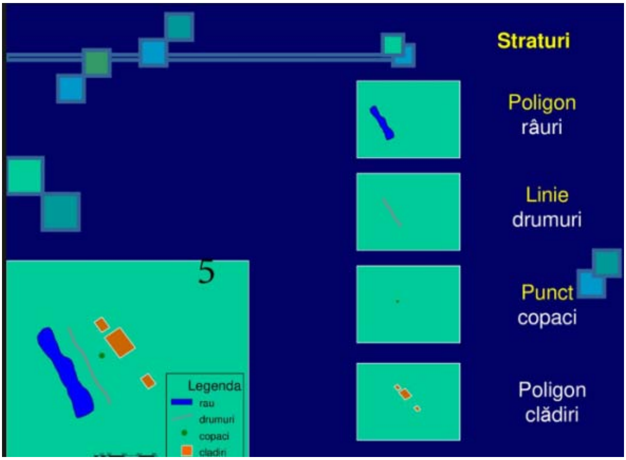


Figure 7.15. How GIS works with an implicit reference [7]

The main data's requirement is the position which has to contain an explicit geographical reference (latitude, longitude, national coordinates) or an implicit reference (location address) (Figure 7.15)[7]. A GIS can link tabular information to these geographic entities, allowing for later analysis.

7.3.7.Symbolization of data

the most important decision can be the choice of how to represent data on a map. The mode of representation determines what the map shows. On some maps you want to represent just the position of objects. The easiest way to do this is to draw all the objects with the same symbol.
Generally, objects can be represented as follows:

1. Unique symbol (clusters or dispersions) (Figure 7.16) [8]

Figure 7.16. Representation by unique symbol [8]

2. Symbol by unique values - sorting according to a characteristic of a certain type (Figure 7.17) [9]

Figure 7.17. Symbol by unique values [9]

3. Symbolization by quantities (gradual colors, gradual symbols and point density maps) (Figure 7.18) [10].

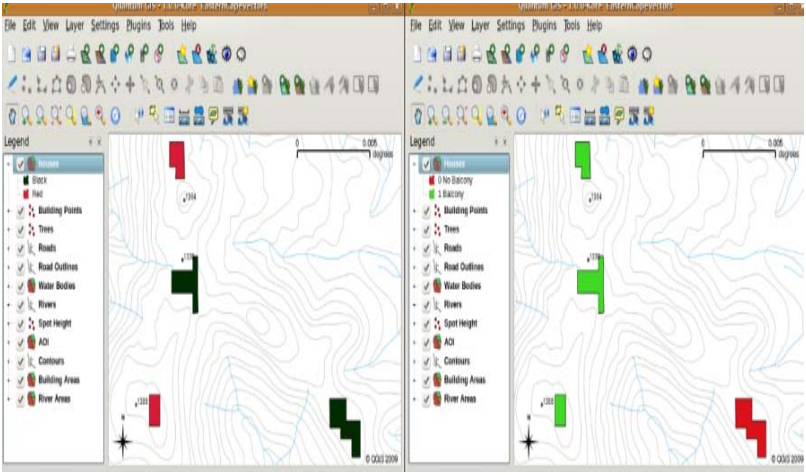


Figure 7.18. Quantity symbol [10]

Entities have attributes and geometry too, so many possibilities are opened up in a GIS application. For example, we can use attribute values to tell to GIS application what colors and style has to use when drawing entities (see figure_style_by_attribute). The process of setting colors and drawing styles is also known as the activity of establishing the symbolism of the entity (Figure 7.19) [10], of VALUE FIELD (Figure 7.20)[10].

Figure 7.19. Activity to establish the symbology of the entity [10]

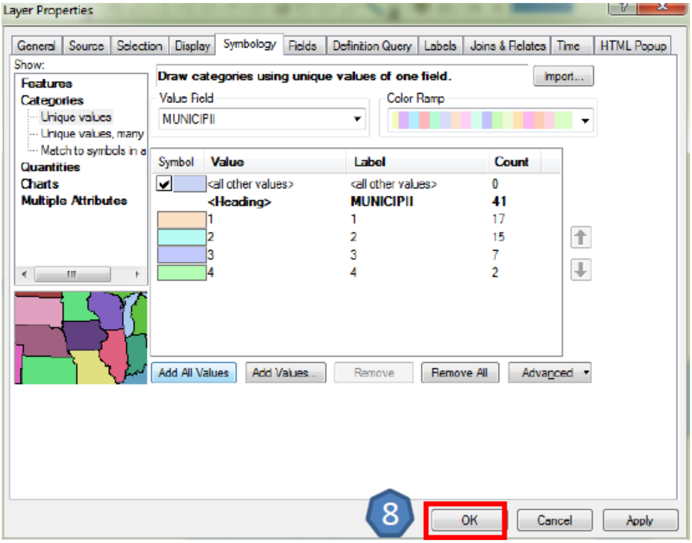


Figure 7.20. Choice of VALUE FIELD-Municipalities [10]

Maps representing quantities

a. Gradual colors (Figure 7.21, Figure 7.22)[10] Value Field – FORESTS

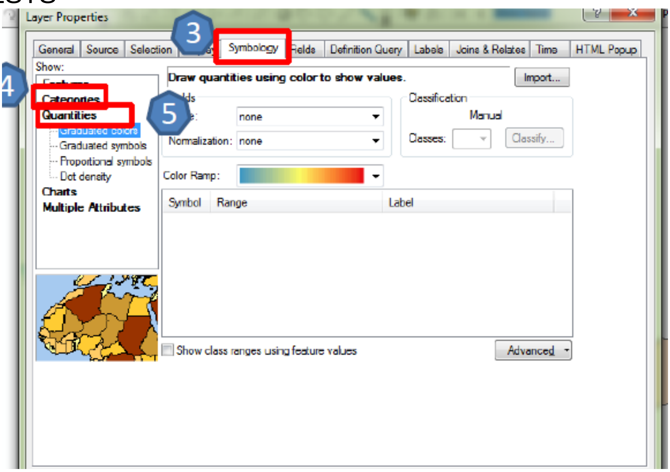
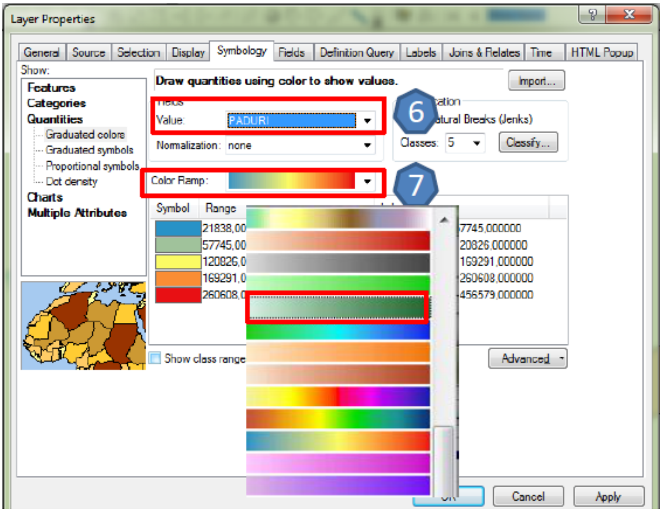


Figure 7.21. Adding another VALUE FIELD [10]



Color Ramp - choosing colors confirms the chosen color range

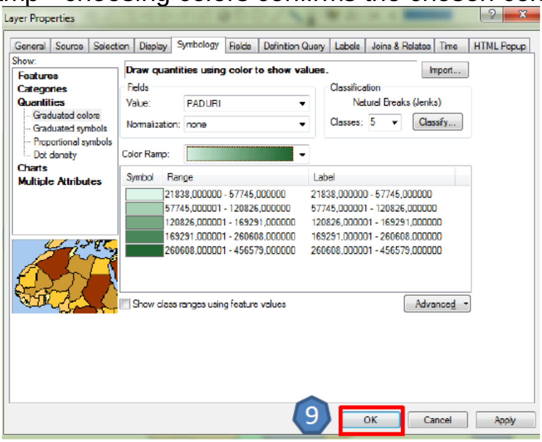


Figure 7.22. Gradual color symbol [10]

b. Gradual symbols

Gradual symbols are used to represent objects within a layer by symbols of different sizes (a predetermined number of classes) depending on the value of an attribute (Figure 7.23) [10].

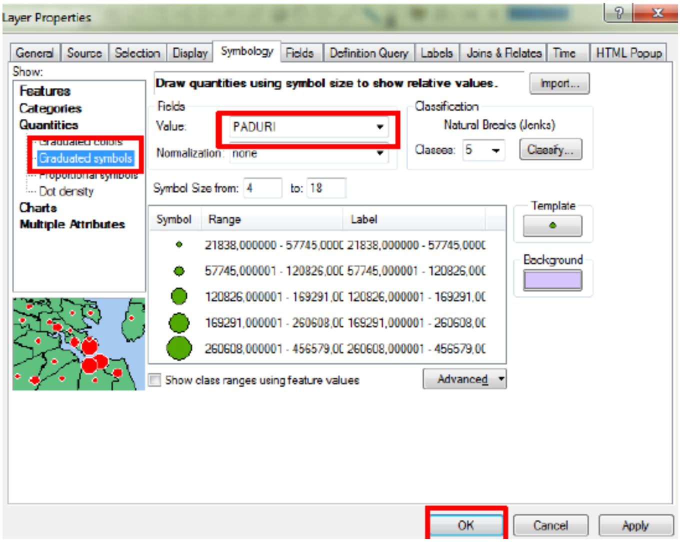


Figure 7.23. Gradual symbol [10]

- Graduated symbols are chosen
- choose the attribute based on which you want to symbolize (*Forests*)

c. Proportional symbols

They are used to represent objects from a layer by symbols of different sizes proportional to the value of an attribute.

To make this representation choose *Proportional symbols* (Figure 7.24)[10]. Choose the attribute based on which you want the symbolization (Forests) and then click OK.

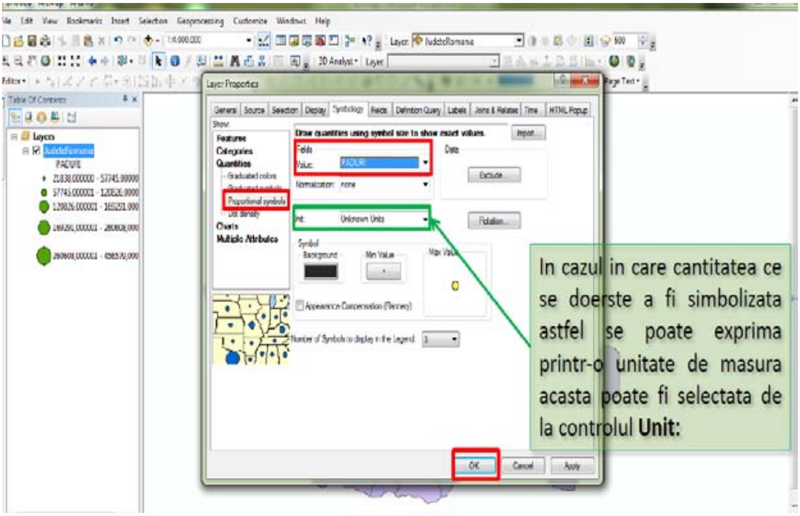
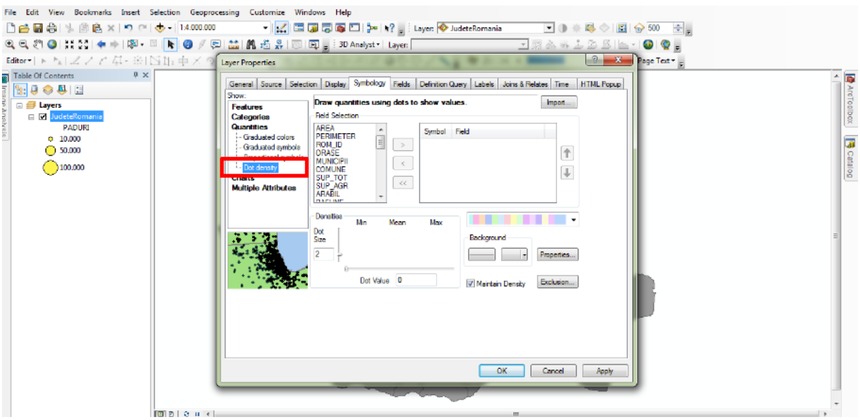


Figure7.24 Symbolize by proportional symbols [10]

d. Maps representing quantities

It is used the DOT DENSITY statement to represent the agglomeration patterns. This helps to identify areas that meet a criterion or require action. Densities of some phenomena or the presence of a phenomenon in a territory that have not a very clear position, are generally represented (Figure 7.25) [10].



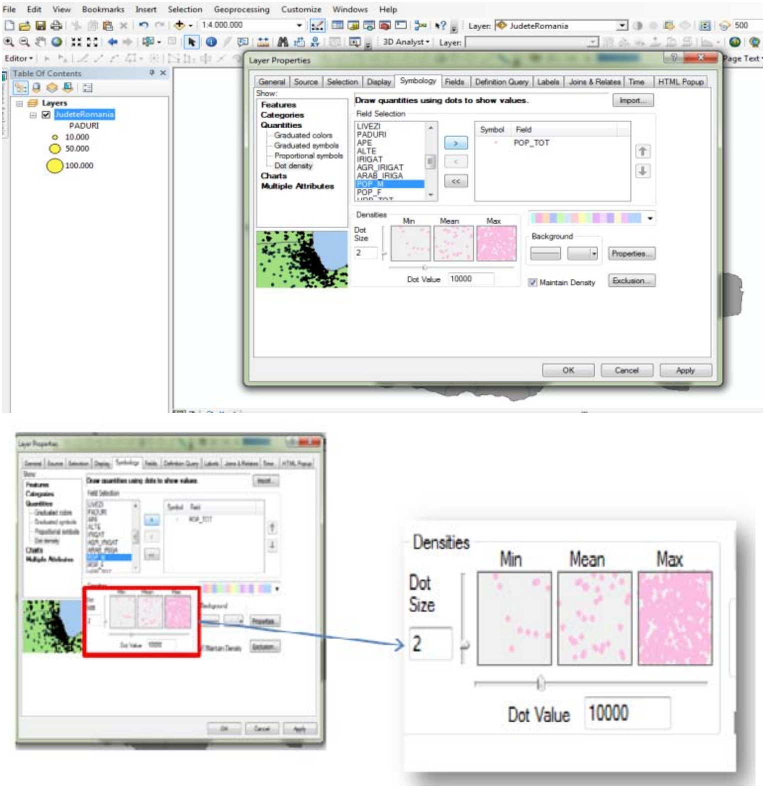


Figure 7.25. Maps representing quantities [10]

7.3.8. Diagram symbolization (graphic) (Figure 7.19) [11].

A. Circle chart (percentage)

This type of representation is used to create comparative graphs for various graphical entities. In the case of this type of graph, the percentage values are represented. The sum of compared values represents 100%. The size of the graph may be equal for all graphical entities, or not equal, depending on the sum of the compared values or another value indicated by the user (Figure 7.26a, Figure 7.26b) [10].

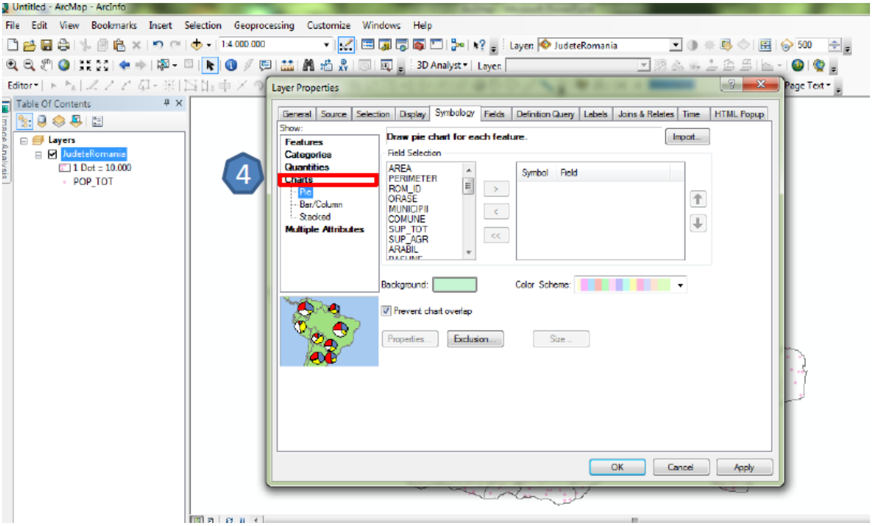


Figure 7.26.a. Chart-Percentage-Chart Choice Symbolize [10]

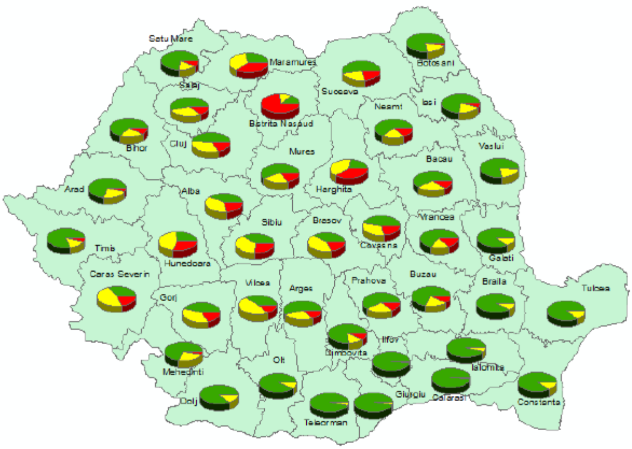


Figure 7.26.b. Diagram-percentage symbolize = choosing the Pie chart type [10]

B. Bar chart

This type of representation is used to create progressive graphs, or to compare various graphical entities. In the case of this type of graph the values are represented as absolute values (Figure 7.27) [10].

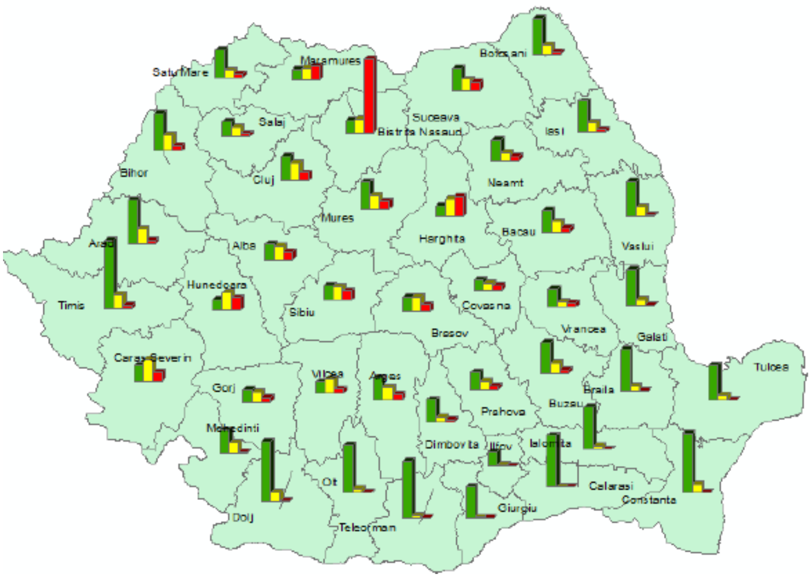


Figure 7.27. Bar-choice symbol = Bar Column chart type [10]

Exit from ArcMap: Click the File menu and choose Exit.

So:

1. Symbolize by a single symbol (Figure 7.28)

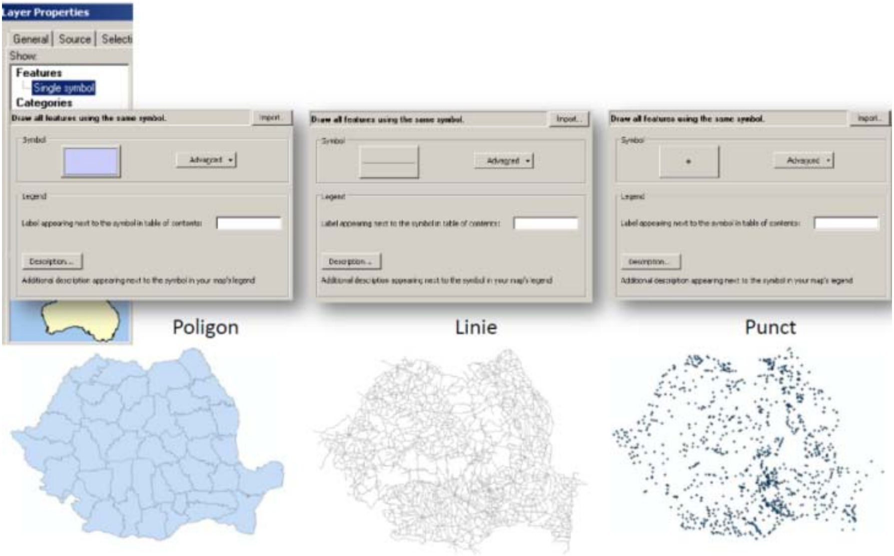


Figure 7.28. Unique symbol symbolize [10]

2. Symbolism with unique values (Figure 7.29) [10]

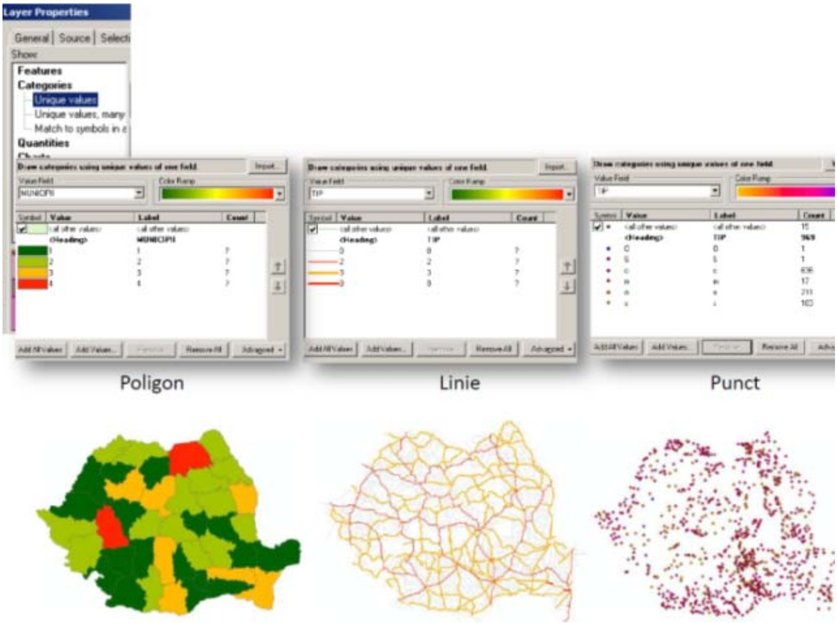


Figure 7.29. Symbolism with unique values [10]

3. Maps representing quantities

A. Gradual colors (Figure 7.302) [10]

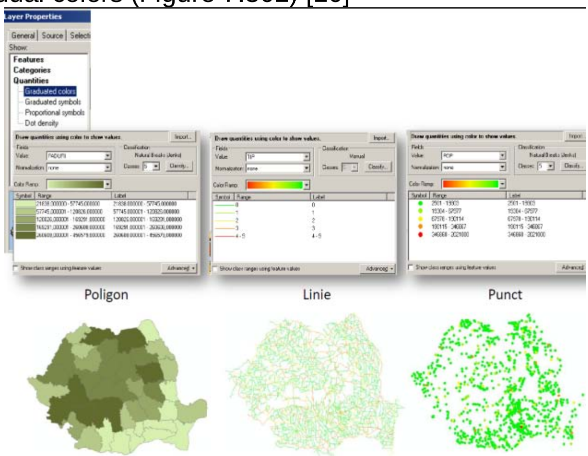


Figure 7.30. Maps representing gradual quantities-colors [10]

B. Gradual symbols (Figure 7.31) [10]

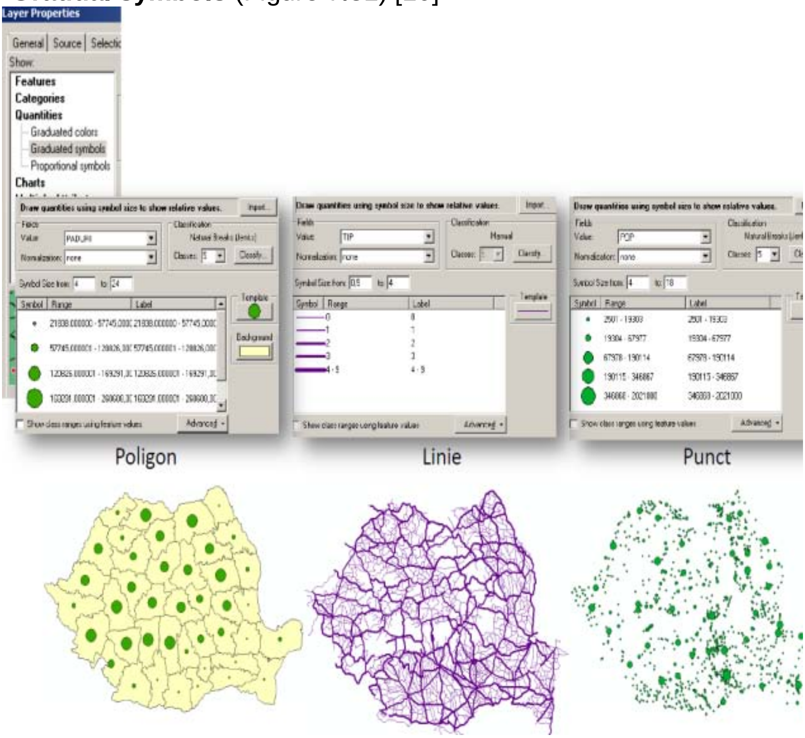


Figure 7.31. Maps representing quantities-Gradual symbols [10]

C. Proportional symbols (Figure 7.32) [10]

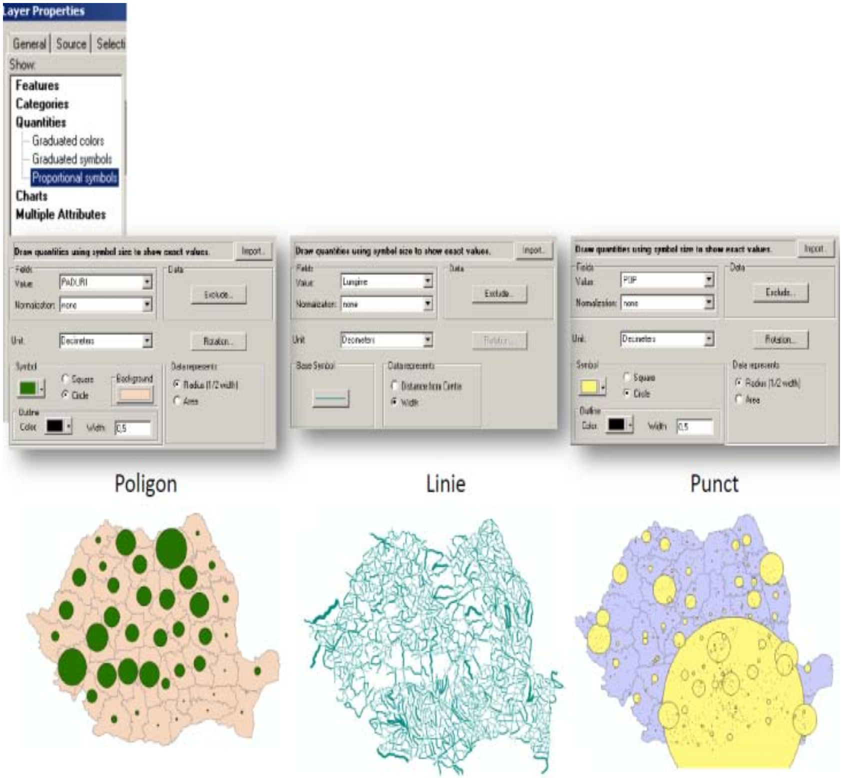


Figure 7.32. Quantity maps - Proportional symbols [10]

D. DOT DENSITY (Figure 7.33) [10]

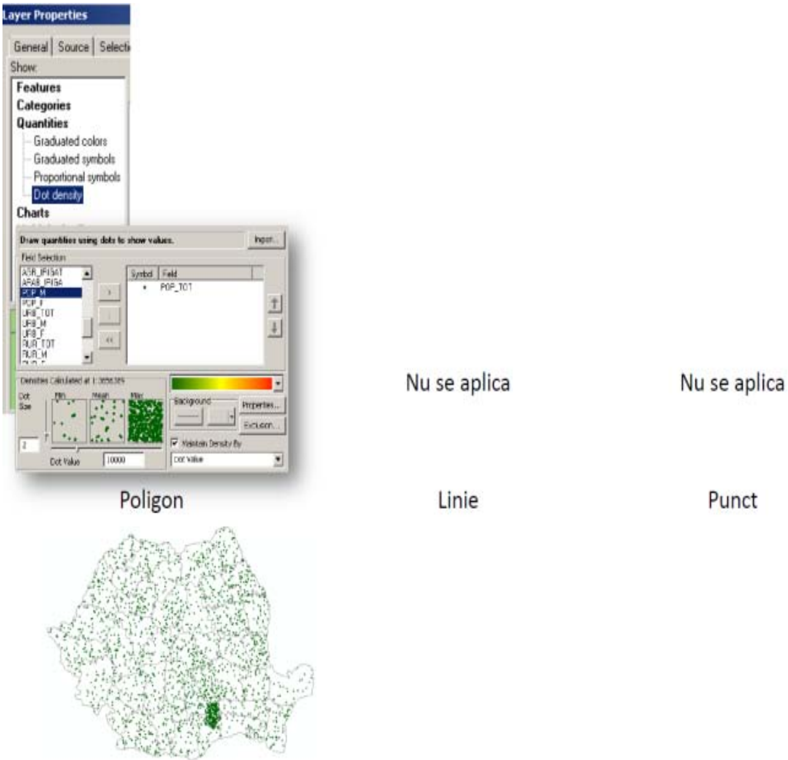


Figure7.33. Quantity Maps - DOT DENSITY [10]

4. Diagram maps

A. Circle chart (percentage) (Figure 7.34) [10]

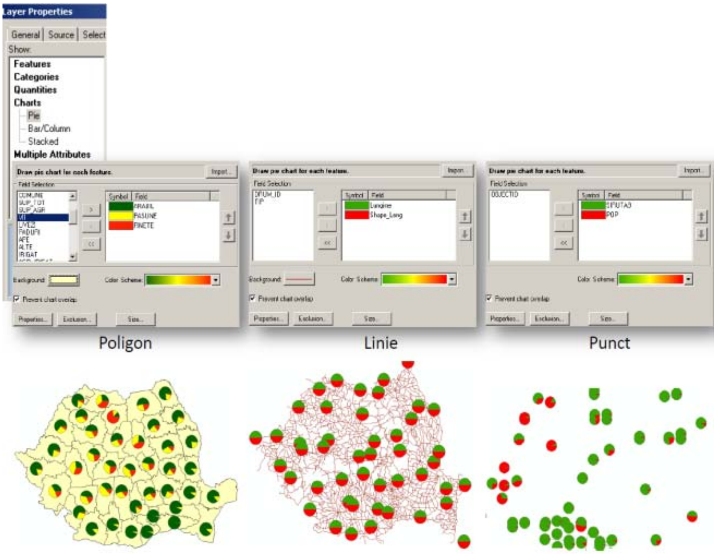


Figure 7.34. Circle chart charts [10]

B. Bar chart (Figure 7.35) [10]

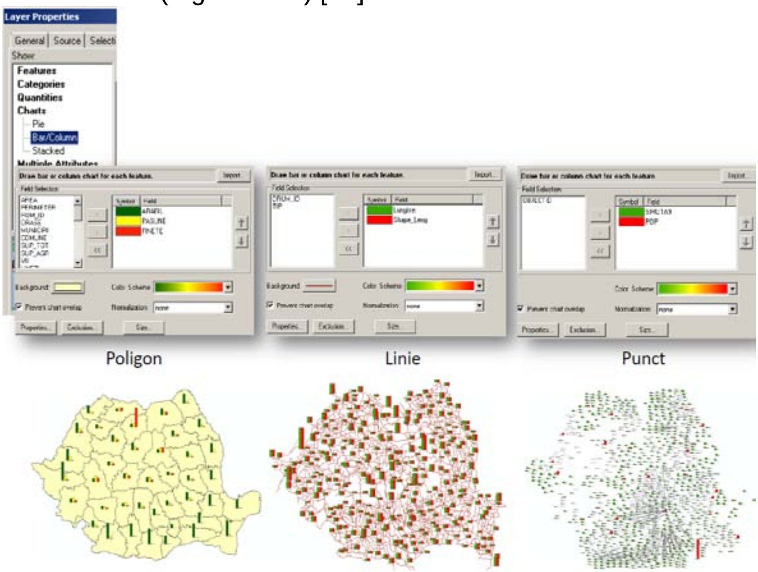


Figure 7.35. Bar Chart Chart Maps [10]

7.3.9. Ways of classifying quantitative data

The way of establishing the classes – establish the minimum and maximum limit of each class - determines the way in which the values of each class are assigned and therefore the way that the map will look [10]. The most common classification schemes are:

• natural breaks,
• quantile,
• Equal intervals
• Standard deviation.

Natural breaks (Jenks)

Classes are divided based on the natural grouping of data value. ArcMap identifies breakpoints by looking for those default data grouping patterns (Figure 7.36) [10].

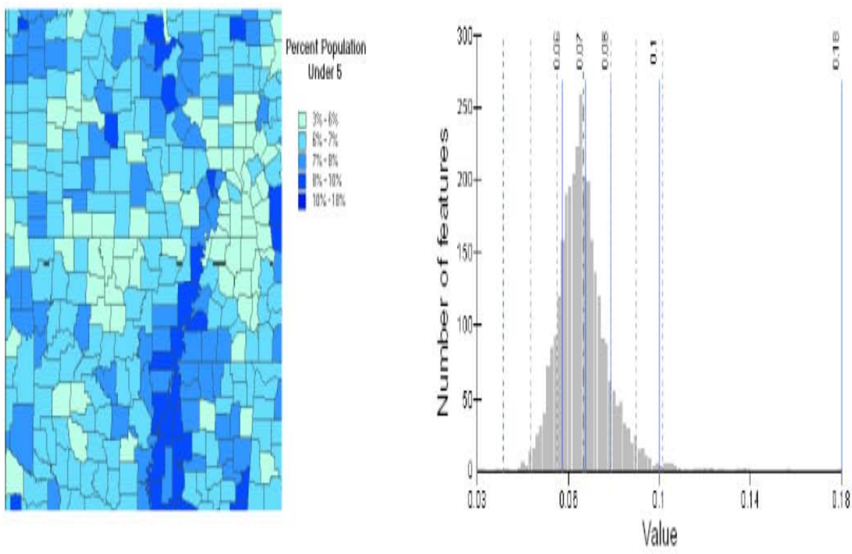


Figure 7.36. Natural breaks [10]

Quantile

Each class contains an equal number of attributes. Such a classification is very appropriate in the case of linear data (Figure 7.37) [10].

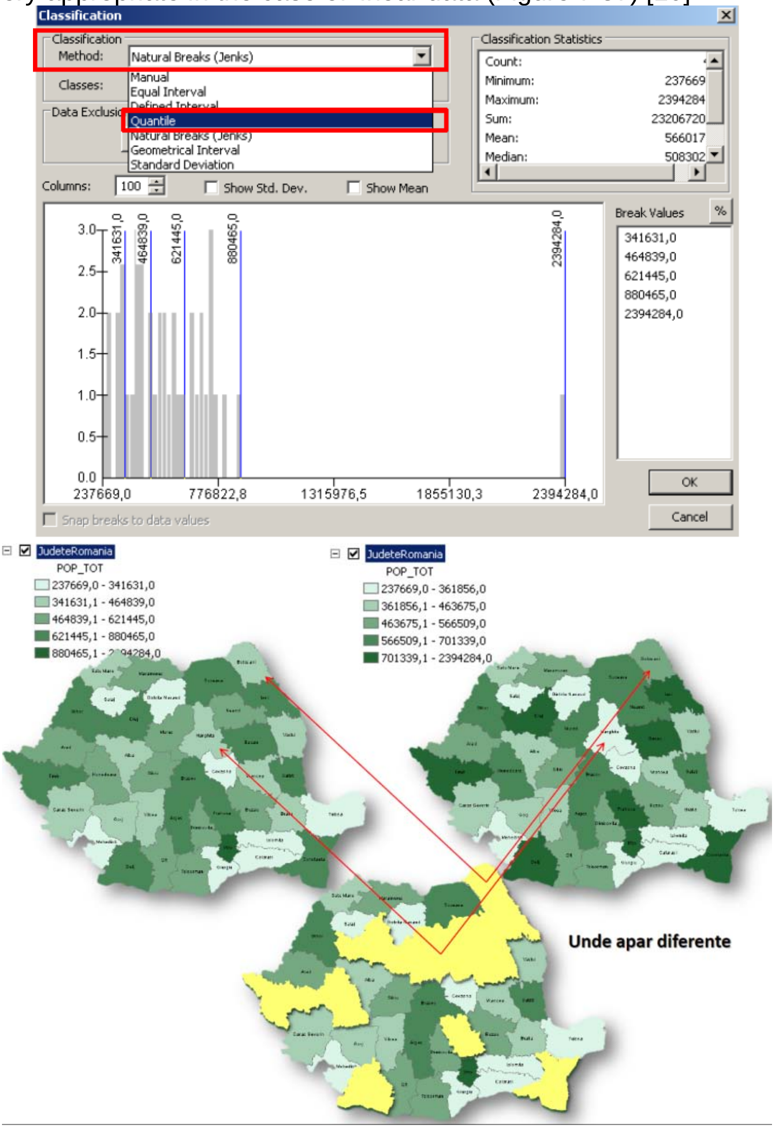


Figure 7.37. Quantiles - choosing the Classification method [10]

Equal interval

This classification scheme divides the string of attribute values into equal substrings (Figure 7.38) [10].

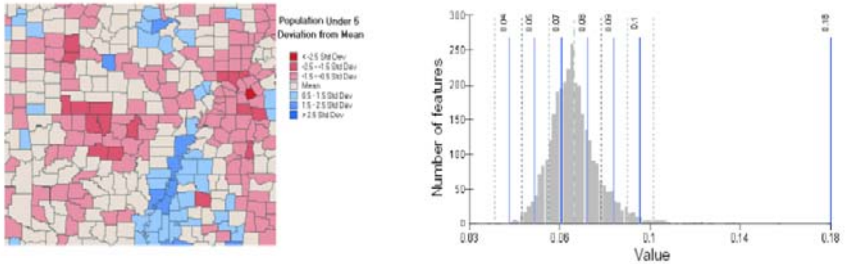
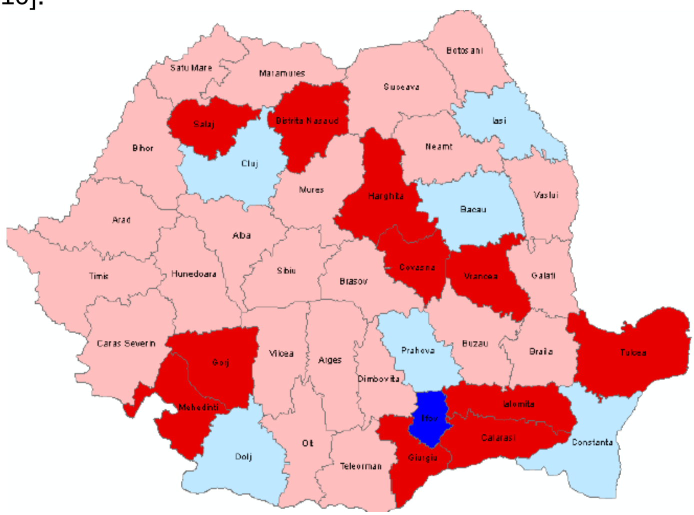


Figure 7.38. Equal intervals [10]

Standard deviation

This classification scheme shows how much an attribute value varies from average. ArcMap calculates the average and then generates classes by adding or subtracting the standard deviation from it. A bicolor slope accentuates the values above (in blue) and below (in red) (Figure 7.39) [10].



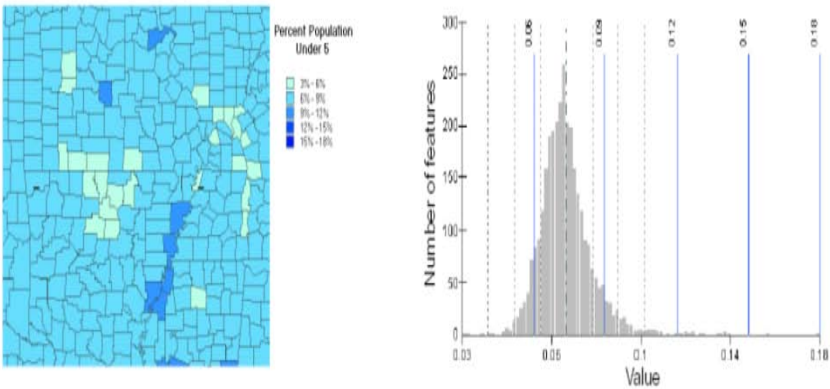


Figure 7.39. Standard deviation [10]

In conclusion, the 4 types of classifications are (Figure 7.40):

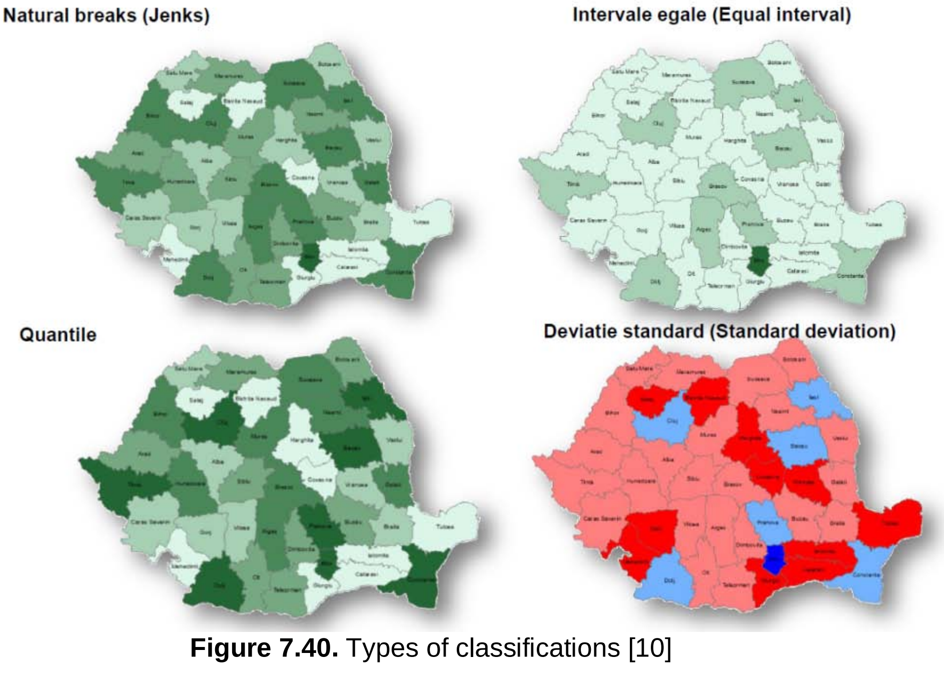


Figure 7.40. Types of classifications [10]

7.4. *Practical class 7.* ArcGis-data, working with the map, geographical entities, tables, attributes.

ARCGIS APPLICATIONS

7.4.1. ArcCatalog

ArcCatalog is a tool used for viewing directory and file structures and organizing GIS data. The catalog tree in the left window is for viewing and organizing directory and file structures. The selected objects on the left are displayed in the window on the right. To view more information about the objects in the Catalog tree, use the Contents, Preview and Metadata buttons (shown in detail later) (Figure 7.41)[11]

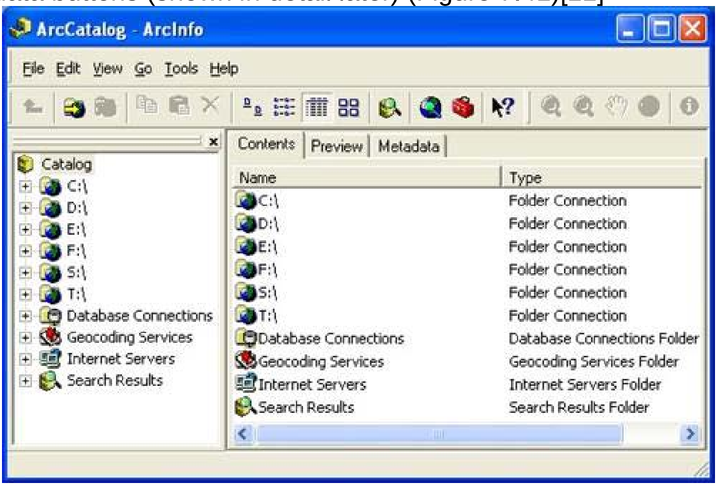


Figure 7.41. ArcCatalog application window [11]

7.4.2. ArcMap

ArcMap is the main application of ArcGIS Desktop. It can be used for data integration and visualization, creating or updating both spatial data and attributes, building maps, performing analyzes (Figure 7.42)[11]

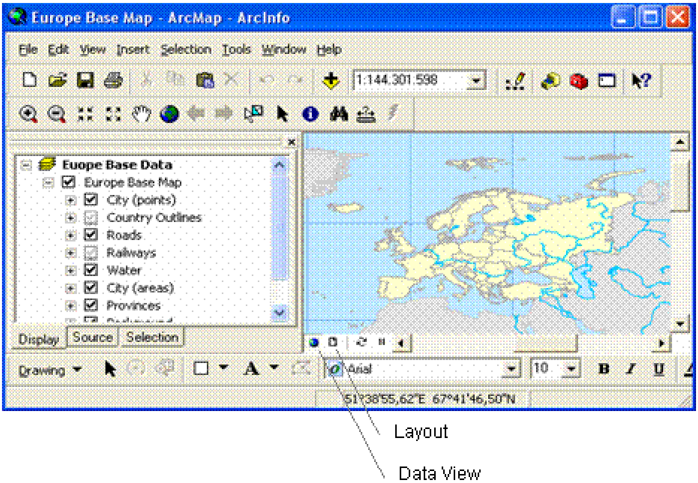


Figure 7.42. ArcMap application window [11]

- ArcMap includes the Zoom in, Zoom out, Pan, Select Elements and Identify toolbars, similar to those in ArcCatalog.
- ArcMap has two display options: Data View and Layout View.
- ArcMap allows the assignment of a representation mode for each layer.
- Layers are organized in data frames. A data frame contains data sets that relate to a project, area, or topic. When you open ArcMap, a data frame called Layers (default / default layer) is created by default.

7.4.3. ArcToolbox

The goal of ArcToolbox application is to simplify GIS tasks through tools or wizards. ArcToolbox is a simple application that contains many tools for geo-processing. There are two versions of ArcToolbox: the full version that comes with ArcInfo and a simplified version for ArcEditor and ArcView. With the tools in ArcToolbox you can perform data analysis and conversion, as well as their administration.

7.4.4. ArcGIS for the marine domain. Marine bathymetry

ArcGIS for Marine Bathymetry is a component of ArcGIS used for managing post-processed bathymetric data and metadata. The product manages raster and vector data from a central geodatabase, called the

Basalometric Information System (**BIS**). **BIS** is used to interact with and manage large raster volumes and points using the ArcGIS for Desktop platform.

Bathymetry manages bathymetric data, stored locally or on a shared network, which can then be processed to create a composite surface model. This composite surface model can be used as a source to create 3D point data for navigation products, to spatially analyze the surface with the ArcGIS Spatial Analyst extension, or to share content on the Web as an image service.

Before bathymetric data is managed by the BIS geodatabase, additional metadata elements can be defined and assigned to each data set to be managed by the system. Query filters can be defined based on metadata values, which are used to identify the specific data sets required for inclusion in the surface model. Sorting rules, also based on metadata values, can be configured to determine the order of rendering of the dataset in the composite surface model.

• Finally, the composite surface model is stored in a workspace and can be used in any of the geographic processing tools or shared on the web as an image service.

Raster data management

• Sending externally stored raster data to a mosaic dataset, removing the need to duplicate raster data storage between a geodatabase and a file system.

• Management of survey metadata and ancillary hydrographic survey information, such as study area, data collection equipment, survey vessel, tidal flow adjustment reports, sound speed reports, survey logs and other survey information. support. Metadata is fully configurable to fit any information an organization captures.

• View and use any existing internal metadata for Bathymetric Attributed Grids networks (.bag files).

Data point management

• Export feature classes of externally stored geodatabase points and create proxy reports to view and manage with other raster datasets using mosaic dataset technology.

• Associate extensive metadata information about each dataset, customized to meet the needs of any organization.

• Extract points from BIS geographic composite surface patterns related to the original datasets, simplifying point management.

Querying and sorting data

• Filter and view ArcMap data using the Explore Bathymetry window.

• Generate custom surfaces interactively using combinations of attribute or spatial filters in the Compose Surface window.

• Prioritize sorting information to display the latest or most accurate data, for example, at the top of the surface in overlapping areas.

Related topics:

• A quick tour of ArcGIS for Marine Bathymetry;

• Essential bathymetric vocabulary.

Utilization of bathymetric data

It can be achieved a comprehensive picture of bathymetry data. It is stored once, it is used several times (Figure 7.43)[11].

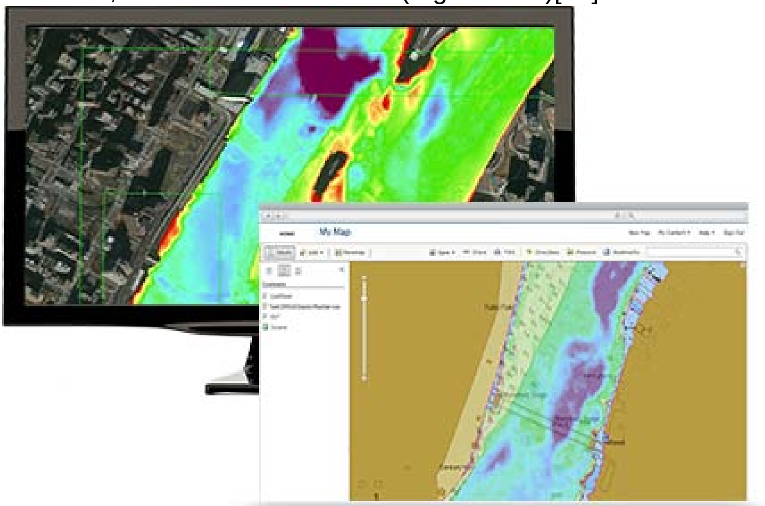


Figure 7.43. Using bathymetric data [11]

The power of GIS over accumulated data

The power of GIS over accumulated data

Bathymetry data is used for making better decision and solving problem in the field of offshore energy, port security, hydrographic services, dredging operations, scientific analysis and many other aspects. ArcGIS for Marine Bathymetry fills out ArcGIS for Marine Mapping for marine mapping, for a smooth and smooth workflow.

Management and reuse of bathymetric data

Easily manage and combine large amount of raster data, bathymetric points and metadata in a GIS environment is the solution that provides spatial analysis tools that allow to know the true value of bathymetric data, analyzing them in a geographical context (Figure 7.44)[11].

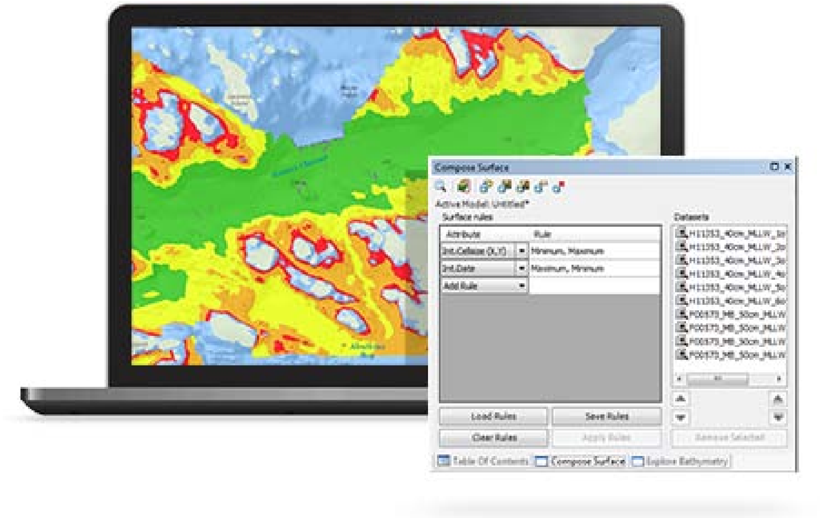


Figure 7.44. Management and reuse of bathymetric data [11]

Efficient use of metadata

Instead of working with data sets that do not contain all information, such as the coordinate system or sensors used, we can have a traceable structure, compatible with S-102, which we can use to discover and analyze data. Then add the desired metadata as needed, from the sensor used to the color of the boat.

Reducing the cost of data storage

Data management does not mean creating another copy in a centralized location. ArcGIS for Marine Bathymetry allows the recording of data sets from their current location and their administration regardless of where they are stored, whether they are locally on the computer or remotely on certain servers.

7.4.5. ArcGIS for emergencies fields

ArcGIS Emergency Management includes a free set of maps, applications, and best practices that helps critical mission management activities in emergency management. As an ArcGIS user, we implement this solution to provide a common operational platform for attenuation, responding, and recovering from threats and threats.

"GIS technology has improved all tactical and operational decision-making, situational awareness, strategic planning, community

involvement and rescue efforts" (Steven Bowden, leader of the GIS delivery and support team, Bundaberg Regional Council) [12].
ArcGIS for emergency management provides ready-to-implement mapping applications. Whether facing natural or man-made disasters or threats, the solution can be used to provide information to the IOC, directors, emergency responders, and the public at all stages of the mission (Figure 7.45).

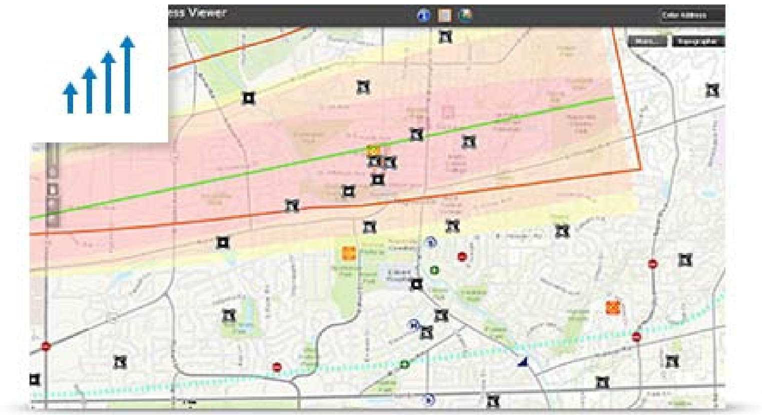


Figure 7.45. ArcGIS for emergency management

We get a suite of apps to help us starting common tasks. For example, the Briefing Book and Impact Summary provide critical information for decision makers, and requests for services for citizens, information about my dangers, and public information allow for the exchange of information between public organizations and response organizations (Figure 7.46).

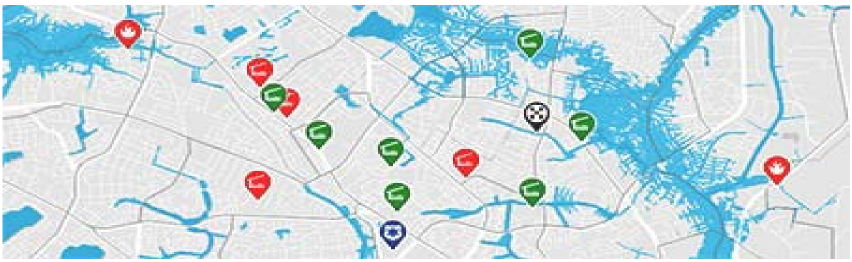


Figure 7.46. ArcGIS Solutions

Agency assistance becomes stronger, develops training plans and responds to emergencies.

• *Preparation*

• Map and model plans before an event occurs, determine their potential impact, visualize critical vulnerabilities, and plan special events (Figure 7.47) [13];

• Mapping and planning potential plans;

• Determine their potential impact;

• Viewing critical vulnerabilities and plan special events.

Figure 7.47. Preparing for an event

Management of community events

Prepare a collection of maps and applications used by government agencies and other stakeholders to enable, coordinate, plan and promote community or special events

It prepares a collection of maps and applications used by government agencies and other stakeholders to enable, coordinate, plan and promote community or special events (Figure 7.48)[13]).

Figure 7.48. Community event management [13]

Create event maps

The event map can be used by organizers and coordinators to create site maps that accompany event authorization applications.

Event coordination can be used by coordinators to facilitate the process of reviewing the participation permit and to manage the status of an authorization application (Figure 7.49)

Figure 7.49. Creating event maps

Examination of authorization applications

Government agencies may review opinion permits, review applications for authorization, and provide comments during the review process.

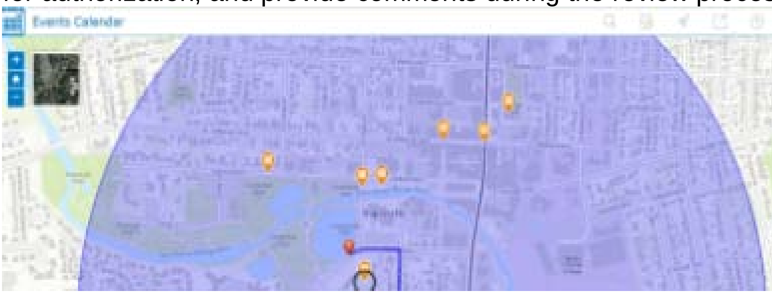


Figure 7.50. Event Locator Application

The Event Locator application allows citizens and visitors to discover and plan a trip, participation in festivals, shows, concerts and other events that take place in a community.

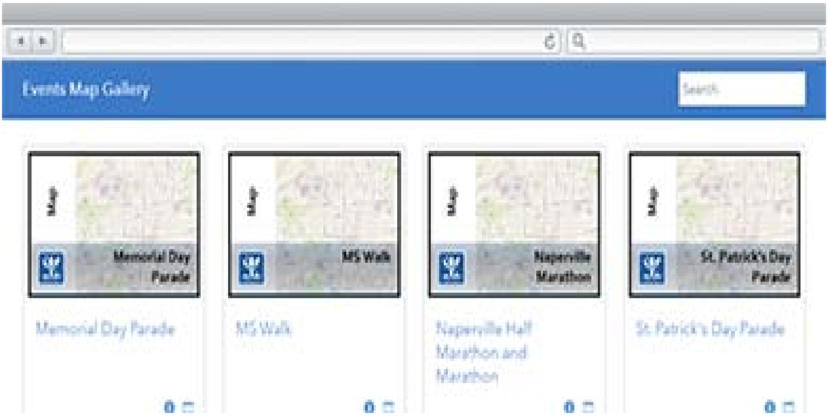


Figure 7.51. Gallery application

Event maps through the Gallery instruction can be used by the general public to access site maps for events occurring in a community (Figure 7.51).

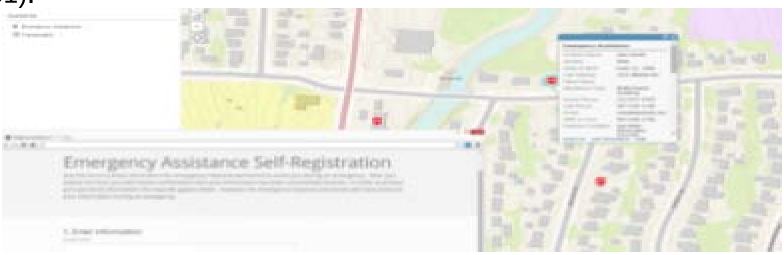


Figure 7.52. Emergency assistance [14]

Emergency assistance (Figure 7.52)
The request for emergency assistance can be used by citizens to provide emergency information organizations with relevant information about themselves to ensure their safety during an emergency incident.

Sharing evacuation areas
The Evacuation Zones application can be used by emergency management organizations to allow the public to determine when evacuations are needed (Figure 7.53)[14].

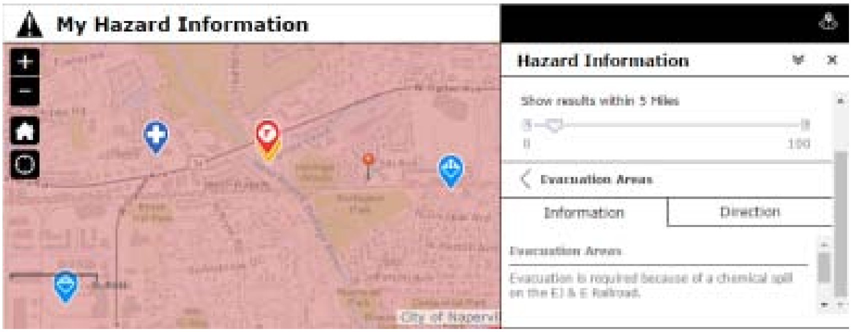


Figure 7.53. Sharing escape areas [14]

Short Personal Incident

The Incident Briefing application can be used by emergency management personnel to provide briefings and reports based on maps in the conditions of the incident and the blue sky (Figure 7.54)[14].

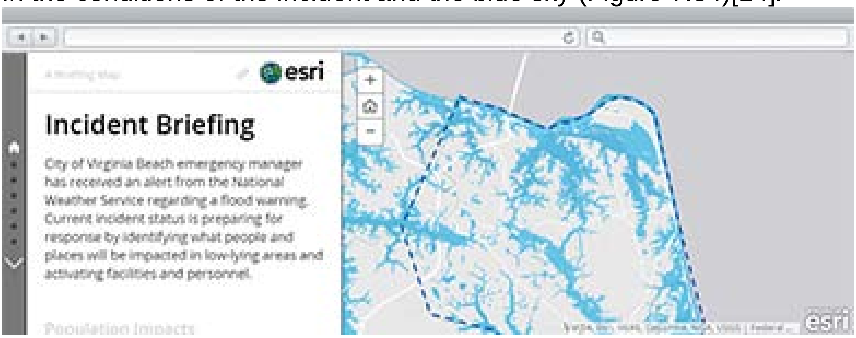


Figure 7.54. Incident Briefing Application

Information on aggregate plots

Community plots can be used by organizations to aggregate authorized collective data and to provide concentrated package maps to key stakeholders (Figure 7.55).

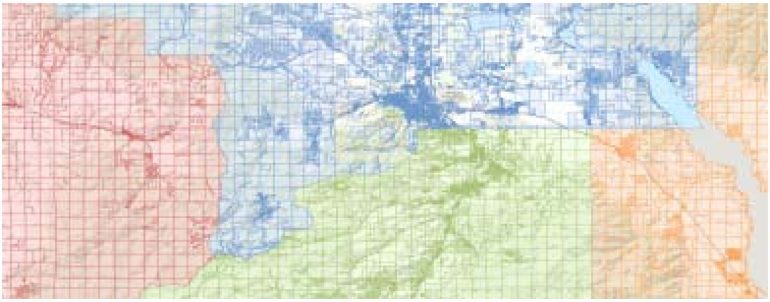


Figure 7.55. Information on aggregate plots

Figure 7.56. Gathering address information

Aggregation of address information

Community addresses can be used by organizations to aggregate authority address data and to provide focused maps and locators to key stakeholders (Figure 7.57).

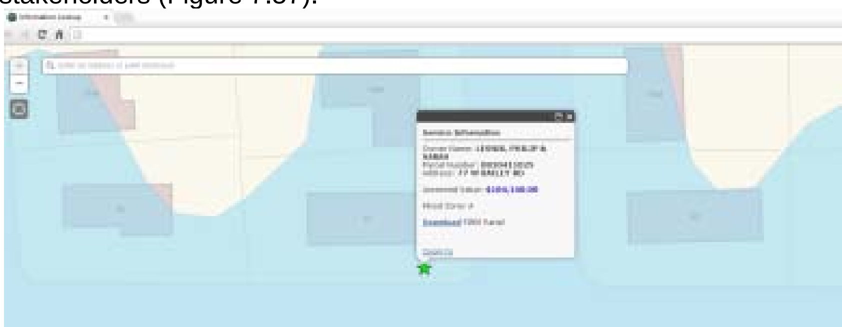


Figure 7.57. Surface area research application

Identification of flood risks

The surface area research application can be used by citizens, land development companies and real estate professionals to find plots affected by FEMA boundaries.

7.5. Lab 7. ArcGis maritime applications.

7.5.1. ArcGIS for the use of water resources

ArcGIS for Water Utilities includes a set of maps, applications and services available for free to support the needs of water services. As an ArcGIS user, you can use this solution to provide tools to improve water utility operations and improve customer service.

ArcGIS for Water Utilities provides ready-to-deploy mapping applications and configurations to maintain water, sewer, and storm distribution networks. Includes apps to manage a main break, provide water consulting, inspect wells, and more.

ArcGIS for Water Utilities includes services, maps, and applications for common tasks (Figure 7.58, Fig. 7.59) .

Figure 7.58. Water delivery application

Figure 7.59. Wastewater collection application

You can get information about the data and improvements of capital projects, information about the activities of the sewerage network, information about overruns, etc.

7.5.2. ArcGIS for the environment. Parks and gardens

ArcGIS for Parks and Gardens is a set of free template maps, applications and workflows that help people carry out joint activities related to stands, botanical gardens, cemeteries, gardens, historic landscapes, nature reserves, parks, similar managed landscapes. Included maps and applications can be used to improve data collection, manage materials, and provide information to the public (Figure 7.60).

Figure 7.60. ArcGIS application for parks and gardens

ArcGIS for Parks and Gardens is free for ArcGIS users, easy to configure, document, and fully supported and extensible (Figure 7.61).

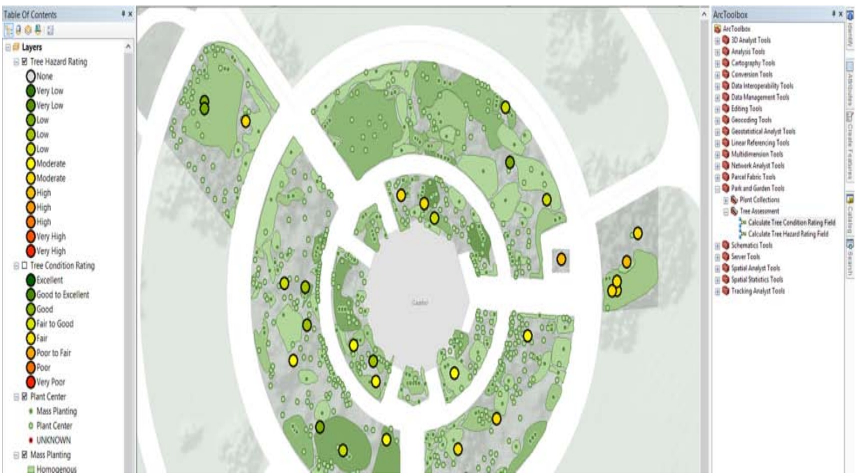


Figure 7.61. ArcGIS application to create concentrated plant maps.

Start quickly mapping your irrigation system with an ArcGIS collector configuration for parks and gardens. It provides a template for creating concentrated irrigation system maps, which can be used to easily create and update irrigation inventory on mobile devices in the garden.

7.5.3. ArcGIS for student use

ArcGIS for Student Use comes with everything you need to learn the skills that will set you apart from your teachers and future employers. Learning technical skills is important and can help you arrange a volunteer opportunity, an internship, or even a job.

Powerful tools

- ArcGIS Desktop Advanced (ArcGIS Pro and ArcMap);
- The most popular ArcGIS Desktop extensions;
- ArcGIS Desktop software updates;
- User account called ArcGIS Online;
- 100 service credits for data storage, access to Premium data and geocoding and analysis;
- A suite of ready-to-use applications for use anywhere, on any device;
- A real-world atlas with maps and data, including access to ESRI Foundation content on thousands of topics;
- Support for installation;
- Unlimited access to e-learning itself on the Esri training website.

7.5.4. ArcGIS application

Environmental Audit, level I for SC OIL TERMINAL S.A. CONSTANŢA

- **Introduction**

SC OIL TERMINAL S.A. is located in Constanţa, Caraiman Street no. 2, Constanţa county, Tel .: 0040-0241 702600, Fax: 0040-0241 694833, Telex 14210, web-site: www.oil-terminal.com, e-mail: office@oil-terminal.com, being registered at Constanta Chamber of Commerce and Industry Nr. J 13/512/1991, cod SURUES 131308801.

The level I environmental balance is elaborated by the National Research - Development Institute for Environmental Protection (ICIM) according to Order no. 184/1997 of the MAPPM regarding the procedure for drawing up the Environmental Assessment (Annex A.2).

When drawing up the Environmental Report, ICIM took into account the following elements:

- documentation submitted by the beneficiary;
- information collected from the field.

- **Location identification and production**

Land use in the site area

The main unit - the headquarters of the enterprise

SC OIL TERMINAL S.A. is located in Constanţa, County,Romania.

- **Production units**:

• NORD warehouse, consisting of:
- NORD I warehouse - located on Caraiman street no. 2 Constanţa;
- NORD II warehouse - located on Justiţiei Street, near Constanţa train station.

• SUD warehouse, located in the southern part of Constanţa, between Constanţa-Mangalia Highway and CF Constanţa - Mangalia (Movila Sara area).

• Port Warehouse - located in the southern part of Constanta port, starting with berth 69 and up to berth 79 inclusive.

The NORD I deposit is adjacent to:
- to the north - the CFR line, towards the Port of Constanţa
- to the south - Caraiman street
- to the east - Constantin Brătescu street
- CFR Constanţa - Mangalia line
- housing area, dispensary
- to the west - the internal warehouse Constanţa
- to the southwest - the access road in the Constanţa internal warehouse

Warehouse NORD II - is in conservation being divided into four distinct areas: 2A, 2B, 2C, 2D.

o Zones 2 A and 2 D are bordered by:
- to the north - the SNC stadium
- residential area, Sandu Chisea street
- section 1 City chemistry (I Chimpex)
- to the east - CFR Constanţa train station
- SC Energia S.A. Constant
- to the south - S.C.Energia S.A. Constant
- CFR Port line (gate 4)
- to the west - zone 2 C - Warehouse NORTH II
- Chemistry city garage line

o Zone 2C - adjacent to:
- to the north - section 1 Chemistry city
- concrete station
- headquarters of the TCMRIC site group
- housing area - str. Geofizică
- to the east - zone 2 D - NORTH Warehouse II
- CFU lines

- section 1 City chemistry
- TCMRIC ballast unloading ramp
- south - CFR line to Port (gate 4)
- to the west - the housing area - Justiţiei street

o Zone 2 B is bordered by:
- to the north - the CFR Bucharest-Constanţa line
- b-dul I.C. Bratianu
- housing area str. Justiţiei
- to the east - the housing area-str. Justice
- to the south - Justiţiei street
- CFU line
- to the west - the stove bottling station

The SUD depot is located in the southern part of Constanţa between the Constanţa - Mangalia national road and the Constanţa - Mangalia railway, the area called Movila Sara.

The PORT warehouse is adjacent to:
- the north - SCIM
- to the west - MIN-METAL Constanţa
- the south - COMVEX
- to the east - the Black Sea

The areas occupied by the OTC site are shown by areas and warehouses in table 1, and in table.2 we present on the warehouses the occupation of the surfaces.

Table 1. Land areas occupied by OTC

Nr. crt.	**Location**	**Area (m^2)**	**Destination**	**Legal regime**
1.	zone B	945.892,79	South warehouse	Ownership Certificate M03 no. 3225
2.	zone B	692.275,19	North 1 warehouse	Ownership Certificate M03 no. 8448 for 413413,17 mp HG 834/1991 unsolved
3.	zone A	405.721,90	North 1 warehouse	
4.	Constanţ a harbour	181.394,00	Harbour warehouse	Rental Contract no. 93/2003 with CNAPMC
	Total	*2.225.283,88*		

Table 2. Occupancy of OTC land areas

Nr. crt.	Area (mp)	North warehouse		South warehouse	Harbour warehouse	TOTAL OTC
		North I	North II			
1.	Built	23.041,07	53.684,32	74.153,98	105.769*	256.648,37
2.	For transport	40.3069,37	139.482,63	602.782,54	-	1.145.334,54
3.	free	18.5783,13	204.834,84	247.665,67	-	638.283,64
4.	Networking	3.0812,43	7.720,11	21.300,60	25.782**	85.615,14
	TOTAL	*69.2275,19*	*405.721,90*	*945.892,79*	*181.394*	*2.225.283,88*
	Occupancy (%)	66,00	50,48	73,8	58,31	66,8

* Berth surface + berth
** Surface bundle of pipes between Port Warehouse and South *Warehouse*

Below is presented the structure of built objectives area, for each warehouse

o The NORD I warehouse occupies a total area of 692,275.19 m^2, of which 23,041.07 sqm are built, composed mainly of:

- administrative headquarters + annexes - 1,547.31 m^2
- material warehouse - 8,212.49 m^2
- pump house - 27,260.80 m^2
- TRAFO stations - 1,050.20 m^2
- warehouses - 3,680.88 m^2
- locker rooms - 254.01 m^2
- manhole valves - 301.64 m^2
- decanter + annexes - 535.60 m^2
- tanks - 44,967.58 m^2
- ramps - 67.20 m^2
- PSI house - 587.33 m^2
- garages - 993.02 m^2
- workshops - 543.13 m^2
- physico-chemical analysis laboratory - 233.03 m^2
- gate cabin - 52.32 m^2
- foam centers - 654.17 m^2

- PECO station - 610.00 m^2
- concrete platforms - 17,799.57 m^2
- other platforms - 9,141.72 m^2
- greenhouse - 653.12 m^2
- parking - 660.00 m^2

o The NORD II warehouse occupies 405,721.90 m^2, of which built area is 53,684.32 m^2, composed mainly of:

- pump house - 538.74 m^2
- post TRAFO - 114.32 m^2
- tanks (water, fuel oil, oil) - 41,044.31 m^2
- tank belt - 1,812.56 m^2
- pipeline pool - 450.00 m^2
- fuel oil basin - 499.83 m^2
- water castle - 41.50 m^2
- gate cabin - 43.50 m^2
- sewer manholes - 1,307.67 m^2
- pump station - 89.00 m^2
- PSI house - 603.12 m^2
- concrete platforms - 7,480.63 m^2
- other platforms - 3,115.58 m^2

o SUD warehouse occupies 945,892.79 m^2, of which the built area is 74,153.98 m^2, as follows:

- laboratory + offices - 432.00 m^2
- warehouses - 1,202.95 m^2
- mechanical workshop - 286.00 m^2
- manhole valves - 1,732.25 m^2
- pump keyboard - 2,379.00 m^2
- treatment plant - 220.00 m^2
- thermal point - 132.00 m^2
- tanks - 60,304.79 m^2
- fuel oil basins - 850.00 m^2
- pools - 1,652.21 m^2
- concrete platforms - 4,126.68 m^2
- other platforms - 7,234.00 m^2
- pump house - 2,669.00 m^2
- PSI draw - 28.00 m^2
- gate cabin - 8.75 m^2
- guardhouse - 492.00 m^2
- nitrogen station - 42.00 m^2
- garage + AMC - 300.00 m^2
- transformation stations - 931.00 m^2

S.C. OIL TERMINAL S.A. pays rent to the Port of Constanta Administration for PORT warehouse area.

Location and topography

The area of Constanţa municipality is located in the south-eastern extremity of the country with the following geographical coordinates: the parallel of 44o15 'and the meridian of 28o30'.

According to H.G. no. 834/1991 pt. establishing the ownership right over the land, topographic measurements were performed with the companies S.C. PROJECT S.A. Constanţa for the South Warehouse (cadastral no. 998) in 1996 and with TOPOCAD SERV S.R.L. for the North Depot (cadastral no. 11745) in February 2004.

Geology and hydrology

Geology - Constanța area belongs, from a geomorphological point of view, to the Pre-Balkan platform. The relief of the area was shaped by water, gradually, from west to east. The character of the platform is highlighted by the weakly wavy deposits, almost flat, which have undergone epirogenetic tilting movements. The land altitudes in the Constanța area are approx. 50-55 m, the general inclination of the region being from west to east.

From a geological point of view, South Dobrogea is a structural unit with specific platform features, with a crystalline base, covered with a thick cover of uncut shapes, Peleozoic, Mesozoic and Neozoic age. Marine sedimentation ends with the Neozoic cycle. South Dobrogea is permanently flooded.

In the Pliocene, due to continental conditions, arid and hot, a clayey, crust-altered crust known as "red Villafronchian clay" is formed.

In the Quaternary, the Constața area evolved as a flooded region, being covered by wind deposits, represented by loess and paleosols, in the form of an almost continuous layer.

The area of Constanța municipality extends on the territory of two peninsular and continental natural units - which from a physical-geographical point of view differ from each other, dividing the city into two distinct geographical units.

The peninsular area of Constanța municipality is characterized by a fragmented relief, finished by a cliff with higher heights in the northwest and slightly lower in the southeast.

The first port arrangements were made inside the dimensions of the small bay in the south of the Constața peninsula. Subsequent needs imposed important extensions that were made through anthropogenic interventions, namely construction of dams and fillings.

In the case of the PORT Warehouse, the site was made by fillings deposited over the marine sediments inside the port, during the 1970s. average of approx. 6.5 m. The fillings were placed on a layer of gray-black sand with the appearance of a shore soaked with water, with medium thickness and a thickness of approx. 0.50 m.

In the SUD Deposit sector, based on the geological surveys carried out over the years, the following soil texture has been identified:

- on the surface, below the vegetal horizon appears a horizon formed by brown clayey powders, yellowish browns (0.4 - 1.3 m);
- followed by yellow loessoid clay powders on a thickness of 1.9 - 4.3 m;
- at a depth between 7.20 and 10.20 m, clay powders continue in horizons of the same texture, but colored differently, with varying percentages of clay (up to 30%);
- follows a horizon of dusty clay (30 - 50%) reddish-brown, brown, sometimes gray-green, with variable thicknesses (0.5 - 6.2 m), with intercalations, sometimes with calcareous concretions;
- below the horizon of dusty clay was intercepted brown or brownish-reddish clay, with low permeability, sometimes with concretions of calcium carbonate, rarely with ferrimanganic stains.

Hydrogeology, hydrology of Dobrogea reveals the existence of three aquifer systems: the Barremian-Jurassic aquifer system, the Sarmatian aquifer system and the Quaternary aquifer system.

Regarding the superficial Quaternary aquifer system, some information is presented, as follows:

- loess is an unconsolidated rock of wind origin. Its porosity is high (40 - 65%), a situation reflected by the high storage capacity due to the small size of the pores, the circulation of water or other fluids, it is left, and the yield capacity is very low. The existence, in the mass of loess, at different levels, of clayey fossil soils (paleosols), with slow development and of the red clays at their base, also discontinuous, creates favorable conditions for the appearance of suspended, non-permanent, local aquifers.
- after the start of irrigation, the natural water deficit in the loess was compensated, so there is currently a surplus of water, highlighted by the presence of a permanent aquifer in the loess, whose levels are very close to the land surface, showing oscillations seasonal.
- the knowledge of the hydrogeological characteristics in the areas of the deposits of petroleum products is very important, because the possible losses are confined and channeled at the level of the groundwater.

For the southern area of Dobrogea is characteristic aquifer karst, consisting of two regional aquifers:
- Deep aquifer of age Upper Jurassic - Lower Cretaceous. The hydraulic diffusion coefficient is about 108 m2 / day, the hydraulic gradient is frequently 5 ‰, and the flow direction is mainly from south to north and secondary to the sea. The total mineralization of the aquifer is between 0.3 and 1 g /l. The main ions are bicarbonates, calcium, magnesium.
- the shallow aquifer, encamped in the Sarmatian limestones. The hydraulic gradient has values between 9-14 ‰, the hydraulic diffusion coefficient is between 50 - 5,000 m2 / day, and the flow direction is from west to east to sea. The total mineralization is approx. 1 g / l. The main ions are bicarbonate, calcium, and near the sea chlorine and sodium.
For the southern area of Dobrogea are characterized three categories of groundwater:
- groundwater, located in Sarmatian quaternary deposits, seasonal;
- deep, with normal mineralization, located in the karst network;
- mineralized, located in the upper and altered part of the crystalline foundation.
The most important aquifer karst system consists of two regional aquifers:
- deep age aquifer Upper Jurassic lower Cretaceous. The Jurassic is the main aquifer formation of Dobrogea, being represented by the upper part of the Doger and a great development of Malm which covers entirely limestone - dolomitic facies;
- the shallow aquifer, encamped in the Sarmatian limestones.
For the SOUTH Depot sector of S.C. OIL TERMINAL S.A., following the hydrographic surveys, it was highlighted that the groundwater level is at variable depths, in the park of 8 x 50,000 m3 being even at the level of 0.50 m up to 0 m.
The knowledge of the hydrogeological characteristics in the areas of the deposits of petroleum products is very important, because the eventual losses of petroleum products are cantoned and channeled at the level of the phreatic canvas, influencing the receiving basins of the coastal lakes.

Location history and future developments
Location history
Company History S.C. OIL TERMINAL S.A. Constanţa is closely linked to the history of the activity of exporting petroleum products through the port of Constanţa, whose beginning can be placed in 1898, since it represents the year of the construction of some tanks by the Romanian STEA Company.

In 1945, the following warehouses and companies for the sale of petroleum products operated in Constanţa municipality: ASTRA ROMÂNĂ, CONCORDIA, ROMÂNO-AMERICANĂ, COLUMBIA, STEAUA ROMÂNĂ UNIREA, which had their own tanks, C.F. and laboratories.
In 1957, all the oil profile units from Dobrogea are reunited in the III Petrol Constanţa base with headquarters in Caraiman street no. 2, the current headquarters of S.C. OIL TERMINAL S.A. Constant.
In 1968, the storage capacity of the North Depot was increased, by building new tanks with a floating oil cover. In 1972, the works of the new Oil Port from Dana 69 from Portul Nou begin, and in 1975, the Constanta Pearl Basin moves to the new Oil Port from Danele 69 - 79, the current Port Warehouse, equipped with loading installations / unloading of petroleum, petrochemical and liquid chemical products.
In the years 1973 - 1974, the oil products warehouse built at Movila Sara, the current South Warehouse, is put into operation.
SC OIL TERMINAL S.A. was established as a joint stock company by Government Decision no. 1200 / 12.11.1990.
In 1983, ILPP "PECO" Constanţa was established, through the CHIMPEX division, taking over the activity of selling petroleum products internally and at the stove bottling station.
In 1985, the oil terminal was separated from CHIMPEX, becoming the company for conditioning and delivery of petroleum and petrochemical products (ICLPPP) Constanţa. The new enterprise is subject to export warehouses I, II, III, IV and import warehouses NORD and SUD, as well as port facilities in the oil basin from berths 69-79.
In 1987 CHIMPEX and ICLPPP were merged again.
SC OIL TERMINAL S.A. is a direct descendant of the Enterprise for the Conditioning of Crude Oil and Petroleum Products, divided from CHIMPEX by Government Decision 514/1990.

Future developments

Future OTC developments are focused on three directions:
o integration of OTC in a multinational crude oil transportation system from the Caspian Sea to Trieste;
o arranging a barge loading installation;
o design and construction of a marine fuel preparation plant.
In the perspective of the globalization of international economic relations and the future economic evolution, predictably upward, of the countries of Central Asia and the Far East, the development of economic corridors to the developed economies of Central and Western Europe acquires a special importance. At the same time, the political and

security interests of the international community require the promotion of southern alternatives to the current Trans-Siberian economic corridor (Moscow - Vladivostok) which, crossing the Black Sea and the Caspian Sea, can capitalize on raw material and fuel resources available in the East. to meet the requirements of developing markets belonging to the states located in the Caspian Basin, with European economic products. In this regard, the countries involved have already launched a sustained campaign to promote economic projects aimed at building this corridor.

In accordance with this international context, with Romania's integration interests in European bodies, it is necessary to adapt the Romanian economy and society in order to play a pivotal role, both as a transit country and as an active participant, on the route of large flows. between Europe and Central Asia. In the context of accelerating the trend of crude oil exports from the Caspian area to Western Europe, the current facilities of S.C. OIL TERMINAL S.A. Constanţa, materialized in 21 tanks with specialized floating lid for crude oil, berths and related pipes, will allow taking over only a part of the Caspian crude oil inflow. The rest could be stored and handled in a new section that TREMINAL OIL wants to develop. This development, exploited at an intense pace, will allow the takeover in transit of at least 3,000,000 tons / month of crude oil in the Caspian Sea basin. It is estimated that in five years the storage spaces for crude oil only at S.C. OIL TERMINAL S.A. will reach over 1 million m3 of storage capacity.

The actual expansion will consist of locating a number of 4-6 high capacity oil tanks on land owned by S.C. OIL TERMINAL S.A. following the existing warehouse located in the southern part of Constanta. For the beginning of the third millennium, in the context of the increasing importance of the oil fields in the Caspian Sea area, S.C. OIL TERMINAL S.A.Constanţa, through its existing capacities, experience of approximately 100 years in the field and attracting some capital sources, aims to enter the European Transport Corridor no. 7 as a cast plate of the oil flow on the East-West direction, being willing to enter into business relations with other brand companies specialized in this very attractive field of activity.

Investment, development in general, is a permanent concern of the company's management. In recent years, investments have been made to provide computer-assisted electronic command and control equipment. High precision flow meters have been purchased for the correct management of the oil products circulated. The investment activity also included a significant number of independent equipment, laboratory equipment corresponding to European standards; the

computer network has been expanded both within the operational services and within the functional services.
Currently, the following activities are ongoing within the unit:
o modernization of pipeline routes;
o replacement of sealing systems for floating lid tanks with large storage capacities (10,000-50,000 tons);
o replacement of existing valves with ascending axis valves, with a butterfly-type upper sealing system and with a ball sealing system;
o phased replacement of pumps with new, more efficient pumps and lower energy consumption;
o installation of telemetry installations (height, temperature, density) in the next four years on all tanks equipped with S.C. OIL TERMINAL S.A.;
o replacement of the connecting hoses from the collection to the tank wagons with multilayer type hoses provided with a system of special couplings for retaining the hose product inside it, considerably reducing the technological loss when disconnecting them;
a decrease in technological consumption, a program launched in 1998;
Among the activities that are in focus and to be implemented are:
o uncovering the collectors from the new ramp and placing them in a collector channel;
o procurement of a waste and sludge separation and control facility.
The investment plan provides for a series of works on all deposits as follows:
North Warehouse:
• Above ground laying of diesel pipes at R 4, 5, 15, 16, 17 - North I;
• Completing the equipment of the diesel ramp with flexible hoses with check valve for unloading products from C.F. tanks;
• Repaired C.F. gutters for collecting the oil product at Rampa Nouă;
• Above ground installation of oil pipelines in the Medea area;
• Rehabilitation of tanks:
- 707 - serpentine;
- 763 - coil and cover;
- 710 - serpentine;
PORT warehouse:
• Rehabilitation of soda lye neutralization station;
• Development of a system for collecting and shipping to the producer of urea losses;
• Modernization of ACN unloading installation;
• Repair of the concrete platform at Dams 69,70, 72;
• Repair of the concrete platform at tanks 27, 28 P;
• Equipping the ramp with new flexible tubes;
• Equipping the berths with new flexible tubes;

• Rehabilitation of dams on the pipe beam;
• Procurement of floating dam for locating oil product leaks;
• Rehabilitation of oil product collection vessel;
• Rehabilitation House creosote pumps.
SOUTH deposit:
• Ramp equipment with flexible hoses equipped with anti-drip fittings for unloading products from C.F. tanks;
• Implementation of the requirements of GD 568/2001 by installing covers with double sealing type PSS at:
- R25S;
- R27S;
- R15S;
- R16S;
• Rehabilitation of tanks:
- R25S;
- R27S;
- R15S;
- R19S
- R16S or R18S;
- R30S;
• Rehabilitation of concrete platform at ramp platforms and arrangement of gutters;
• Rehabilitation of pipes, manholes - "hump" area;
• Rehabilitation of domestic sewerage;
• Rehabilitation of technological pipelines in the Park 3x50,000.

Possibility of soil pollution

In all three warehouses - NORTH, PORT and SOUTH, for soil protection at all installations (loading - unloading ramps, pump houses, tank parks, keyboards) there are sewerage networks, drains, drains that ensure the capture of accidental technological losses , washing plant water, rainwater, etc. and directing them to treatment plants.
In order to ensure the protection of the neighboring areas, of the tank parks, each tank is provided with earth protection dams, in order to form a retention basin for liquid petroleum, petrochemical and chemical products, in case of spills of products on large areas.
Following notifications from the population and from the company's specialists regarding the presence of petroleum products in the groundwater and soil in the area of the NORTH and SOUTH Deposits, S.C. OIL TERMINAL S.A. conducted a series of hydrological, biogeotechnical, redaesthetic and radioactive tracer surveys through

research contracts with S.C. PROFIL S.A. Constanta, S.C. GERA SRL and the Institute of Atomic Physics Bucharest, in the period 1990-1999.

Approx. 80 drillings at different depths until the detection of groundwater, in the area of the NORD Depot - MEDEEA reservoir park (R 11-14), in the vicinity of the companies CARMECO, VINVICO, FORTUNA, Abator residential district, UNIREA reservoir park, towards the tunnel CFR and Poarta 2 Caraiman street.

In the case of the SOUTH Depot, the areas of Gate 6- North Agigea Gate, the unloading ramp for white petroleum products, the tank of the tank 35 were investigated.

At the NORD depot following investigations by S.C. PROFIL S.A. and S.C. GERA S.R.L. the following conclusions were drawn:

a) MEDEEA tank park - 40 boreholes Φ 3 ”.

The presence of petroleum products was found at groundwater level at depths between 2.60 - 2.70 m in the southeastern extremity and 5.50 - 5.70 m in the area of reservoirs 11-12.

Current and accidental losses of petroleum products over several years of operation have led to soaking of soils on variable thicknesses and runoff on the line of the highest slope, depending on the permeability of the layers.

In order to stop the flow of groundwater infested with oil product to the neighboring units and for the depollution in time of the area, it is necessary to establish a dam in the direction of flow, and to lower the groundwater level, by:

- waterproof membrane (molded wall made of self-hardening mud) on the contour of the enclosure and lowering the groundwater level by pumping;
- horizontal drainage network with a depth of 5.5 - 6.0 m and pumping water from the drain collectors;
- network of interception wells perpendicular to the direction of flow and pumping of the collected water in the internal sewerage network.

The last option is considered to be the most economical.

b) the area of the companies VINVICO, FORTUNA, the canned fish factory - a 2 ”manual drilling.

The presence of the petroleum product was found at a depth of 6.50 - 7.50 m, coming from the R 13 tank in the MEDEEA park, on a route that goes towards Caraiman street, crossing it through the right of S.C. VINVICO S.A. Constant. From here, the underground route reaches the CFR ramp, which directs it almost rectilinearly to the east, through the courtyard of S.C. FORTUNA S.A. and the Fish Cannery, to S.C. CARMECO S.A.

It was recommended to empty the R 13 tank, to control and remedy the defects, to make some hydrological drilling networks or observation wells, to periodically empty them, to dig a drainage ditch, located on the route of petroleum products.

As a result of the studies carried out, the MEDEEA tank park where petrol and diesel were stored has undergone the following changes:

- the petrol was transferred to the SUD depot;
- the 5 product tanks were subjected to capital repairs by total replacement of the bottom, mantle, cover and adjacent equipment (valves, valve chambers at the base of the tank), underground laying of pipes, breathing valves.

c) UNIREA Park - 7 Φ 3 ”boreholes (approx. 80 mm)

The presence of groundwater was found in the entire investigated area, at depths between 0.80 - 6.30 m, with various petroleum products due to preferential migration, in the order: gasoline, diesel, fuel oil, depending on their viscosity.

It was recommended to check the bottoms of the tanks in the park, the location of some drainage boreholes, the periodic monitoring of the presence of petroleum products.

Based on the recommendations from the research works in the UNIREA tank park, the following changes were made:

- petrol and diesel were removed from the tanks;
- a sewerage system was made with the direction of sewage and rainwater runoff to a collector well, which also takes over the wastewater from R6 and R7 (rented tanks from Petromar), after which the water is sent by pumping in the separator of petroleum products.

d) Oil pipelines between the NORTH Warehouse and the SOUTH Warehouse (Salciilor and Amurgului streets - km 4-5).

10 Φ 3 ”boreholes were drilled at depths between 4.00 –6.00 m on the two streets, starting from the bundle of pipes perpendicular to them.

Slight pollution of oil product was observed at depths between 1.50-4.50 m, and groundwater at 2.75 m does not show the film of oil product.

As a result of the research, in order to prevent contamination of the area with petroleum products, S.C. OIL TERMINAL S.A. replaced the pipe bundle 90%.

At the South Warehouse, following investigations by S.C. Profile S.A., S.C. Gera S.R.L. and IFA Bucharest highlighted the following:

a) Unloading ramp for white petroleum products

4 deep drillings (15.00 m) of Φ 8 5/8 ”and 2 drillings of 8.00 m with Φ 3” were made up to the groundwater level.

The presence of petroleum products was found at depths between 1.9 - 4.3 m in the soil. The groundwater is cantoned in two districts, with depths between 7.00 - 8.00 m in the end areas of the ramp.
It was concluded that the area of the unloading ramp for white petroleum products is affected by an excess of water from the SUD Depot, the water that carries oil product from losses and that must be captured in the sewerage network.
In order to stop the flow of water loaded with petroleum products to the base of the cliff, several possibilities are recommended.
- waterproof bentonite membrane embedded in clay;
- deep drainage (horizontal and vertical);
- network of interception wells perpendicular to the direction of water flow and pumping in the oil products separator.

The last possibility is considered the most economically advantageous - the well network.

b) Gate 6 area - Agigea North Port

Drilling was carried out at a depth of 6.00 - 7.00 m. The biogeophysical expertise performed in the area of the cliff in the eastern part of the SOUTH Depot highlighted the existence of two sources of loss of petroleum products underground - the northern end of the ramp , between lines 1 and 2, and the tank R37.

It was recommended to carry out the control and repairs at the base of the R37 tank, to repair the oil products pipelines and the sewerage system, as well as to carry out a network of hydrological drilling for periodic observation and emptying.

Tank 35 - 3 manual drillings with depths of 8.00 m arranged around the tank at 120 oC.

Degradation of the R35 tank was observed due to high groundwater levels, for which reason it was proposed to restore the stormwater drainage system, monitor the settlements, strengthen the foundations, remove the losses from the fire and sewerage network.
Compared to those presented, it can be highlighted that all hydrogeological investigations have reported losses of petroleum products in the soil up to groundwater level, which requires measures to reduce losses in loading-unloading operations at ramps, tanks, pipelines and execution groundwater works.

Based on the investigations, measures were taken at the SUD Depot to repair the bottoms of most of the tanks, and the R35 tank is under repair.
A project was also drawn up to repair drains, bottoms, covers and to build a new sealing system for R32 and R35 (PSS emission reduction system).
In the case of the PORT Depot which is on a land recovered from the sea, with gravel filling, the groundwater level is in communication with the marine waters.
Groundwater has a salinity close to that of Black Sea water and under these conditions, infiltration of pollutants into the soil can directly affect the marine environment.
Waste storage
From the general activity of S.C. OIL TERMINAL S.A. resulting in household waste and industrial waste.
Household waste is handed over to S.C. SALPORT S.A., headquartered inside the Port of Constanta. From the NORTH Depot (I + II) it is handed over to S.C. ECOSAL SRL a monthly quantity of 1.2 tons of household waste.
According to the service contract no. 51/2000 S.C. SALPORT S.A. takes over monthly from S.C.OIL TERMINAL S.A. (Offices + Caraiman Street Warehouse and SUD Warehouse) a quantity of 25 cubic meters of household waste, stored in 4 containers of 5 cubic meters each.
Industrial waste consists of wood, paper, ferrous and non-ferrous materials, textiles, tires, concrete slabs, batteries, oil sludge.
Recoverable waste is stored in landscaped spaces, then handed over to REMAT units (iron, bronze, brass, copper, tires) or is recovered internally (textiles, wood, oil sludge), and some materials (concrete slabs, bricks, cubic stone , deer timber) are sold to the company's employees.
The waste situation is presented annually to the Constanţa Environmental Protection Agency, at the end of the first quarter of the following year. The following table shows the types of waste generated with the related codes, quantities, as well as the storage / recovery method.

Table 3. The waste management plan under S.C. TERMINAL OIL

Nr. crt.	Waste type	Cod identification (HG nr. 856/2002)	Amount	Issue of origin	Mode of storage / recovery
1.	Wood processing waste: sawdust, wood chips, chips	03 01 05		Carpentry workshop of the Mechanical Section	- In the past: use as fuel - Currently: stored for accidental pollution in the premises (absorbent petroleum products)
2.	Oily wastes and liquid fuel wastes: engine and transmission oils	13 02 05*		Engines and hydraulic transmission systems	S.N.P. PETROM
3.	Oily wastes and wastes from liquid fuels: other fuels (mixtures)	13 07 03		Engines and transmission systems	- S.C. PETCO SERV NAV - S.C. FORTIUS EUROVIAL S.R.L. - S.C. ECOPETROLEUM S.A. Constanţa
4.	Packaging waste: paper and cardboard packaging	15 01 01	2 t/yea	Supply	S.C. REMAT S.A.
5.	End-of-life tires	16 01 03	1,8 tone/yea (2002)	Replacing used tires	In bulk, in specially arranged enclosures, some even covered

Nr. crt.	Waste type	Cod identification (HG nr. 856/2002)	Amount	Issue of origin	Mode of storage / recovery
6.	Hoses contaminated with petroleum products	16 03 03*	8,5 tone/an (2002)	Replacement due to deterioration, aging	Stored in bulk on a concrete, uncovered platform, specially arranged
7.	Lead acid batteries	16 06 01*	1.100 kg/an (2002)	Replacing used batteries	In bulk, in the covered enclosure, specially arranged
8.	Wastes containing petroleum products, including crude oil (sludge)	16 07 08*	105,4-167,2 t/trim. (2002-2003)	Variable quantities, depending on product quality and stored quantity	It is not stored temporarily
9.	Construction and demolition waste: wood	17 02 01	44 tone/an (2002)	Repair work, including replacement of CF sleepers, not impregnated	In bulk, in the uncovered enclosure, on a concrete platform
10.	Construction and demolition waste: plastic waste	17 02 03	18 kg stoc	Faulting telephone sets	Storage in the recoverable warehouse
11.	Construction and demolition waste: copper, bronze, brass	17 04 01	155 kg/an (2002)	Processing, failure, repair of installations and equipment	Metal containers, placed in a covered enclosure

Nr. crt.	Waste type	Cod identification (HG nr. 856/2002)	Amount	Issue of origin	Mode of storage / recovery
12.	Construction and demolition waste: aluminum	17 04 02	1.660 kg/an (2002)	Processing, failure, repair of installations and equipment	Uncovered concrete platform
13.	Construction and demolition waste: lead	17 04 03	800 kg/yea	Processing, failure, repair of installations and equipment	Metal containers without lid, placed in a covered enclosure (mechanical workshop)
14.	Construction and demolition waste: iron and steel	17 04 05	367.500 kg/yea	Mechanical workshop, decommissioning of some installations and equipment	Platformă betonată neacoperită
15.	Wastes from sanitary activities: sharp objects	18 01 01	2 kg/mon	Prevention, diagnosis and treatment activities	În incinta dispensarului, în cutii speciale de carton
16.	Municipal and similar waste: textiles	20 01 11	10 kg/mon	Replacement of tablecloths and sheets	Stocate în saci, în incinta acoperită
17.	Mixed municipal waste	20 03 01	70 m^3/mon	employee activity	Stocate în recipienţi tip europubela

Electric capacitors / transformers

The electricity supply is made from the national energy system through the CONEL Constanţa Electric Networks Branch.

SC OIL TERMINAL S.A. has a contract for the delivery of electricity to large consumers with RENEL Constanţa, no. 35/26 September 1996.

At the level of 1998, compared to the planned consumption of 9,534 Mwh, 8,465 Mwh were consumed, and in 1999 in the period January-November, compared to the planned 7,570 MWh, 6,249 MWh were consumed.

SC OIL TERMINAL S.A. Constanţa is equipped and uses at the three warehouses NORD, PORT and SUD, electrical transformers to reduce the supply voltage of 20 kV high voltage overhead power lines, to which all electric motors and work equipment are supplied.

For each deposit the situation is as follows:

NORD warehouse

Power is supplied by two 20 kV lines and two 400 kVA transformers, 20/6 kV belonging to CONEL, 6 kV busbars and departures to PT 17, 87, 113 (6 kV cables) belong to S.C. OIL TERMINAL S.A. Constant.

Transformer substations (PT) have 6 / 0.4 kV transformers. The working voltage is 0.4 kV.

Transformers:

- 2 x 1600 kVA
- 2 x 1000 kVA
- 6 x 630 kVA

PORT warehouse

The supply is made from the 110/6 kV Port 2 station belonging to CONEL. From the station leave 6 KV cables that supply PT - adana 6k transformers. The working voltage is 0.4 kV.

Transformers:

- 2 x 1,600 kVA;
- 3 x 630 kVA;
- 1 x 180 kVA.

SOUTH warehouse

The power supply of the warehouse is made from the 110/20/6 kV Petrol station, belonging to CONEL. The 6 kV cables that supply PT 1 and PT 2 liquid chemicals, which belong to the company, leave the station. PTs have 6 / 0.4 kV transformers. The working voltage is 0.4 kV.

Transformers:

- 2 x 1,000 kVA;
- 4 x 630 kVA;
- 1 x 400 kVA.

The electrical transformers are installed in special rooms called transformer stations (PT), to which only the authorized workers from CONEL have access.
As for the electric capacitors, they are located in their own reactive energy compensation installations, they have a rectangular shape, they are mounted in special rooms, on supports called compensation modules.
The supervision and maintenance of electric capacitors is provided by the company's own staff.
The situation of electric capacitors, on deposits, is as follows:
NORTH deposit:
- 12 x 25 Kvar / 6 kV;
- 45 x 15 Kvar / 0.4 kV - two adjustment steps;
- 6 x 16.3 Kvar / 0.4 kV;
- 30 x 21.6 Kvar / 0.4 kV.

PORT warehouse:
- 13 x 20 Kvar / 0.4 kV - two adjustment steps;

SOUTH deposit:
- 24 x 25.4 Kvar / 6 kV;
- 11 x 10 Kvar / 0.4 kV - two adjustment stages;
- 4 x 15 Kvar / 0.4 kV.

Underground and / or surface high voltage cables can be found in the S.C. OIL TERMINAL S.A. only up to TRAFO stations, in CONEL operation.

Area security
In terms of area protection, S.C. OIL TERMINAL S.A. is organized as follows:
- All warehouses are properly lit at night. The enclosures are surrounded by 3 m high concrete fences with iron cornices.
- At the NORD Warehouse, security is provided with its own staff, certified by the local police, and who work in 3 shifts.
- At the PORT and SUD Depots are guards employed by the Wallachia Security and Security Agency and the company's own guards.

The security system is checked with the help of the duty officer, with the car running non-stop.
Security lighting works in all interior areas and on the perimeter.
The security staff is equipped with gas pistols and a steel bullet.
There are wired and radio alarm systems.
The specialized personnel of the company ensures the security of the equipment and installations, continuously, at all work points.

Despite all the measures taken by the beneficiary and presented above, however, there have been and are numerous "thefts" from drilling, especially, as happens in many oil areas in the country, oil products. As has been seen in the field, of course, these thefts cause local pollution, although it has been observed that they are well "organized". The beneficiary assures that he will take additional protection and security measures, in the place where this phenomenon was seen it is quite difficult to protect, because being located near the landfill, many "individuals" come who deal only with these thefts.
The developer of the paper was not permanently present on the spot to be able to ascertain the burglaries or acts of vandalism that may take place within the present objective. The above mentioned were found during the trips made on the spot as well as in the beneficiary's statements.
The annex specifies the situations of the committed deviations concluded on 31.05.2004 and 12.07.2004.
SC OIL TERMINAL S.A. has a plan of defense against disasters, in case of magnitude VIII earthquakes, chemical accident at storage capacities, mass fires, epidemics and episodes, falls of cosmic objects.
The application of the disaster defense plan is sent by order from the Inspectorate for Emergency Situations Constanta, by the decision of the prefect.
The company is equipped with means of protection and intervention in case of chemical or nuclear accident, as follows:

Fire protection measures
SC OIL TERMINAL S.A. is taken into account for interventions in case of need by the Inspectorate for Emergency Situations "Dobrogea" of Constanţa County.
At the company level there is a PSI Technical Commission which includes the technical director - president, warehouse managers, job leaders and union representatives. Each warehouse has a fire brigade equipped with fire trucks and fixed installations, composed of hydrants and COBRA type cannons.
The NORD and SUD depots are also equipped with fire extinguishing cannons with aeromechanical foam, and the PORT Depot is provided with SILVANI type cannons with aeromechanical foam for intervention to extinguish a fire, on board the ships in the related berths.
Each tank is equipped with fencing dams that take up 2/3 of the tank capacity in case of damage.
The pump housings are equipped with a chemical foam extinguishing system.

The tanks of petroleum and chemical products are provided with fixed installations, operated from the chemical foam boxes, which in case of fire interrupt the contact with the air and lead to the extinction of the fire.

Labor protection and hygiene at work

SC OIL TERMINAL S.A. for the activities they carry out, they have authorizations and operating permits, granted by the sanitary, sanitary-veterinary and labor protection authorities, as well as by other bodies empowered at territorial or national level:

• Authorization no. 88 / 07.07.1997, issued by the State Inspection for boiler control;

• Authorization for possession and use of toxic products and substances no. 68 / 09.02.1993 and no. 10312 / 19.11.1992 - Laboratory IV SUD, issued by the Sanitary Police Inspectorate and the Labor Protection Inspectorate;

• Authorization no. 1101 / 7.11.1995 - buffet storage premises, issued by the State Sanitary Veterinary Inspectorate;

• Sanitary authorizations for operation, on warehouses and objectives, issued by the Inspectorate of Sanitary Police and Preventive Medicine, namely:

- 4588 / 10.07.1992 - Warehouse I, production body;
- 4590 / 10.07.1992 - laboratory IV South;
- 459 / 10.07.1992 - Depozit III Port, Dana 69 Port;
- 4593 / 10.07.1992 - Toxicology Laboratory;
- 4594 / 10.07.1992 - Company headquarters;
- 4599 / 10.07.1992 - Depollution, berth 70 Port;
- 4600 / 10.07.1992 - CFU Caraiman;
- 8437 / 18.12.1992 - Depozit Castrol, Dana 69 Port;
- 6511 / 04.04.1994 - Port Midia Terminal;
- 1303 / 10.01.1996 - Metering installations;
- 3010 / 28.06.1996 - Diesel loaded diesel;
- 3011 / 28.06.1996 - PECO Station;
- 2444 / 10.05.1997 - Chemical laundry.

• Labor Protection Authorization no. 6187 / 21.12.1999 - issued by the Territorial State Inspectorate for Labor Protection - Constanţa County - MMPS.

SC OIL TERMINAL S.A. has a labor protection department staffed with personnel trained and certified by MMPS - Territorial State Inspectorate for Labor Protection Constanta and control workshop, maintenance, repair of resuscitation devices. Each warehouse has officials appointed by internal decisions, with the role of training and verifying the knowledge of the staff, and of notifying any unforeseen situations, which could contravene the norms of labor protection.

The members of the labor protection department, together with the specialists from the Health and Safety Committee, permanently analyze the risk factors for occupational injuries and illnesses in order to prevent them and improve the working conditions. There is a register of accidents and specific causes to highlight accidents. Any work accident is reported to the State Territorial Inspectorate for Labor Protection.

According with the laws and inland norms, the employees benefit from protective equipment and hygienic-sanitary materials granted periodically. The need for equipment and materials is established annually, for each job.

SC OIL TERMINAL S.A. is always ready to intervene in case of damage, accidents or intoxication. In this sense, each warehouse is organized on intervention formations and with the necessary equipment for respiratory protection: sanitary kits, gas masks with filter cartridges, masks with supply hose, compressed air devices, resuscitation device.

Intoxications and burns with toxic, caustic, explosive or flammable substances, neutralizing substances are used with the application of first aid measures.

For gastric diseases of the respiratory system, skin, eyes are used substances such as: antibiotics, camotusin, codeine, potassium permanganate bicarbonate, paraffin oil, cooking oils.

Among the potential risk factors for occupational injury or illness, generated by the means of production and work processes and environmental conditions, the following can be highlighted:

- moving machine parts;
- non-toxic powders in the working atmosphere;
- thermal radiation;
- working in the atmosphere of flammable gases or vapors or explosions;
- working with toxic, caustic, flammable chemicals at the loading-unloading ramp, pump houses, tanks, keyboards, etc .;
- work at height;
- high or low air temperature;
- noise at pump houses, compressor houses;
- electric current - direct or indirect touch;
- pressure vessels.

To prevent these risk factors, the company takes a series of technical and organizational measures such as:

- providing individual protection and work equipment for service personnel, by jobs and sectors;
- marking dangerous areas;
- equipping the tanks with access stairs, railings and working means at height;
- periodic determination of noxious substances in the working atmosphere, endowment of personnel with means of protection against gases, provision of protection food, ensuring ventilation in closed spaces, niches in laboratories;
- thermal insulation of containers and pipes;
- determination of noise levels at workplaces (pump houses, compressor houses), application of measures to combat noise and isolation of noise sources;
- execution of interventions at electrical installations only with qualified personnel in the profession of electrician;
- execution of interventions at pressure installations only with qualified personnel, trained and authorized according to ISCIR prescriptions.

In accordance with the Norms of occupational medicine approved by the Order of the Minister of Health no. 19957/1995, S.C. OIL TERMINAL S.A. periodically determines the concentrations of toxic substances in the atmosphere of the work area and monitors the compliance with the permissible limits.

In 1998 and 1999, the Constanţa Public Health Inspectorate carried out toxicological determinations on warehouses and workplaces in 198 sampling in the working atmosphere with hydrocarbons, gasoline, diesel, fuel oil, crude oil, reactor oil, methanol, lye, soda, octanol, isobutanol, carbon tetrachloride, sulfuric acid, cyanides, toluene, carbon monoxide, for which 63 analysis reports were issued.

The jobs where the expertises were performed are:
- ramps of petroleum products;
- soda leaching ramp;
- tanks;
- oil pump houses;
- liquid chemical pump houses;
- physico-chemical analysis laboratories;
- changing rooms;
- storage enclosures;
- metering installations - filter cleaning;
- retention wells;
- mooring port;
- wastewater separators;
- keyboards;

- chemical laundry;
- transport sector - car workshop;
- mechanical repair sector - carpentry workshop;
- PSI depollution sector;
- tank cleaning;
- MIDIA terminal.

Toxicological determinations were made in March-September of each year, most analyzes were performed on petroleum products (gasoline, diesel, fuel oil, crude oil) in June, July, August, when evaporation reaches high levels. The results of the analytical determinations are generally within the admissible limits, except for the CTC Laboratory sector at the PORT Warehouse where there were exceedances of the content of gasoline, sulfuric acid, carbon tetrachloride, cyanides according to the analysis bulletins 97 / 08.06.1999, 100 /03.06.1999, 46 / 14.08.1998, 51 / 28.04.1998.

Also, at the tanks and the loading-unloading ramp of lye soda, exceedances of the allowed limit for lye were reported, according to the analysis bulletins 82 and 83/3 June 1999, 103/21 July 1999.

At the PORT Warehouse, exceedances of the gasoline content were reported at the filter metering-cleaning installations, according to the analysis bulletin 101/2 June 1999.

In the auxiliary sector, there were reported exceedances of the chemical content in the air in the transport - battery charging - sulfuric acid - BA99 / 01.06.1999, in the carpentry workshop - acetone - BA102 / 01.06.1999, the PSI depollution compartment - oxide carbon –BA 86 / 28.03.1998.

For the respective sectors, measures are required to reduce the noxious substances by ensuring the local and general ventilation systems, ensuring the sealing of the installations during the operations of chemical transport, endowment of the risk laboratories, neutralization of the excess toxic substances and others.

Regarding the noise, the important sources of noise are the pump houses, where determinations of noise levels were made in the three warehouses and according to the determined bulletins 457 - 477 from 18.06.1992, the determined levels were in the range 82 - 87 DB (A) on the basis of which the service personnel is equipped with earmuffs.

Wastewater disposal

SC OIL TERMINAL S.A. consumes drinking water for domestic and industrial purposes, as well as groundwater through dug wells and seawater for extinguishing fires.

For the supply of drinking water and the taking over of domestic and industrial wastewater and meteoric waters, S.C. OIL TERMINAL S.A. has concluded the contracts:
- Contract no. 118 Bis from 08.09.1996 with a validity of 5 years - contractor Regia Autonomă Judeţean de Apa Constanţa, based on which drinking water can be taken from the supply network in an annual quantity of approx. 600 thousand cubic meters for the NORTH Warehouse.
- Special contract no. 93 AC / 1999 - on the supply of drinking water and the takeover of domestic and meteoric wastewater - contractor C.N. Maritime Ports Administration S.A. Constanţa - Port Services Branch.
Annually the PORT warehouse takes approx. 100 thousand cubic meters of drinking water and discharges 80 thousand cubic meters of wastewater.
For the delivery of groundwater for industry, the company has a subscription contract with A.N. APELE ROMÂNE S.A., Dobrogea Litoral Water Directorate - Constanţa Water Management System regarding the delivery of products and the provision of water management services no. 423 of 2004. According to the Minutes of finding and reception no. 05 / 08.07.2004, a volume of water taken from the ground of 9,416 m3 was established, for May, broken down as follows:
- North Depot I - 8,582 m3;
- North Depot II - 834 m3;
- South deposit - 0 m3.
Also, for the wastewater discharged into the Black Sea, through berth 69, a monthly flow of 4,528 m3 was registered.
Also based on the Water Management Authorization no. 31/1995 issued by RA Apele Române - Constanţa branch is evacuated in the Black Sea - Dana 69 - an annual quantity of 180 thousand m3 of domestic, technological and rainwater wastewater from the PORT and SUD Depot.
Table 4 shows the annual quantities of drinking water supplied and wastewater taken over by RAJA Constanţa.

Table 4. The situation of drinking water supply and wastewater discharge at S.C. OIL TERMINAL S.A. (CONTRACT RAJA Constanţa no. 118 Bis from 08.09.1997).

Specifications	U.M.	Annual quantities
Drinking water - Constanţa - Warehouse NORTH - Agigea - South Warehouse	mii m^3	669,432 480,000 189,432

Wastewater, added water and condensate, not returned to I.E. Constant	mii m^3	480,000

Within the NORD warehouse there are two wells dug through which water is taken from the ground, used exclusively to ensure the stock of fire water and the pressure in the hydrant network. The wells have the following characteristics

Well no.1	Well no.2
H = 350 m	H = 155 m
NHS = 33 m	NHS = 36 m
NHD = 47 m	NHD = 38 m

The wells are equipped with vertical submersible electric pumps, HEBE, Qn = 20 m^3 / h, Pn = 10 kW.

At the SUD Depot there are two other wells for taking water from the underground, in order to provide fire water to the tanks and the hydrant network. The characteristics of the wells in the SOUTH Warehouse are:

Well no.1	Well no.2
H = 53 m	H = 370 m
NHS = 28 m	NHS = 29 m
NHD = 31.5 m	NHD = 38.5 m

Domestic and technological wastewater - resulting from leaks from tanks, washing from ramps, pipes, hoses, tanks, reservoirs, etc., water from ballast, as well as rainwater is pre-treated in gravity separators, related to each deposit.

The current situation at the level of each warehouse is presented below:

NORD warehouse

The NORD landfill uses drinking water for domestic and industrial purposes for cleaning operations and extinguishing fires.

Drinking water is taken from the RAJA Constanţa network on a contract basis, and the purified wastewater is discharged into the sewerage network of the same county autonomous utility.

Wastewater is the result of a mixture of water used for various purposes, with products spilled during transfer, storage, conditioning or delivery operations.

For this purpose, the following sources are mentioned:

- toilets;
- physico-chemical analysis laboratory;
- CF and car loading-unloading ramp platforms;
- entrainment of products in the water used for cleaning platforms, installations, containers, pipes;

- accidental spills of products due to failure of some installations or excessive filling of some containers;
- entrainment in the water coming from precipitations of the products spread on the surface of the lands or work platforms;
- separate water discharges at the bottom of product tanks lighter than water and immiscible with it.

The 6,500 m long sewerage network is composed of concrete pipes on the plug with Dn = 500 and steel pipe and manholes.

NORD Depot II

The wastewater, after the second stage of separation is sent to the sewerage network of RAJA Constanţa, with a flow of 1,225 m3 / day, from where through the section U6 they are discharged to SPO Poarta 6.

From the NORD II deposit, the treated waters are discharged into the Black Sea Dana 34, with a flow of 125 m^3 / day.

PORT warehouse

The PORT depot uses drinking water for domestic and industrial purposes for cleaning operations of some installations and for extinguishing fires. Daily water consumption is approx. 150 mc.

The wastewater resulting from the activity of the PORT Depot comes from several sources, namely:
- toilets;
- physico-chemical analysis laboratory;
- ballast and wash water from oil tankers;
- wastewater from water sewerage with petroleum products (oil products ramp, leaks from tanks, pump house, keyboards, taps);
- impure meteoric waters from the enclosure;
- wastewater with various impurities brought from the neutralization station.

After separation, the treated water is discharged into the port aquarium.

Through its own physico-chemical analysis laboratory, S.C. OIL TERMINAL S.A. controls the quality status of the wastewater before entering the purification plant, as well as at its exit, at the point of discharge into the marine environment.

SOUTH warehouse

The SUD landfill uses drinking water for domestic and industrial purposes for cleaning operations of some installations and for extinguishing fires.

Wastewater has the following sources:
- toilets;
- physico-chemical analysis laboratory;
- CF loading - unloading ramp platforms;

- entrainment of petroleum and chemical products in the water used for cleaning installations, containers, pipes;
- accidental spills of products due to failure of some installations or excessive filling of some containers;
- entrainment in the water coming from precipitations of the products spread on the land surface or on the work platforms;
- separate water discharges at the bottom of product tanks lighter than water and immiscible with them.

The mixed waters from the two PORT and SUD depots are discharged into the Black Sea, at Dana 69. The discharged water flow is 763 m3 / day, of which 500 m3 / day from the SUD Depot, and 263 m3 / day from the Depot I'M WEARING.

The quality of wastewater at the entrance to the separators of petroleum products and at the outlet is controlled in the laboratories of physico-chemical analysis of each warehouse and compared with the regulations in force - NTPA 001/1997 for discharge into natural resources and STAS 4706/1988 - Surface water and NTPA 002/1997 for evacuation in urban sewerage networks.

The monitoring of wastewater discharges is performed periodically as follows:

- daily, through its own laboratory at the evacuation into the Black Sea;
- weekly, through its own laboratory and RAJA laboratory, at the evacuation in the RAJA sewerage network;
- weekly, through its own laboratory, at the evacuation in the APC sewerage network.

The separators have continuous operation, only on the mechanical stage. The effluent from the separators is analyzed physico-chemically once every 12 hours.

The separators are not equipped with automation loading tanks, the flow rates at the water inlet and outlet are not measured and they are cleaned manually twice a year.

The situation of realizing the allocations regarding the volumes of water taken and / or discharged in the period 2003-2004, reported by A.N. APELE ROMÂNE S.A. - The Dobrogea Litoral Waters Directorate is presented in table 5., And in table 6. is the situation of monitoring the quality indicators for wastewater discharged from the company's platform.

Table 5. The balance of water supply and discharge in the period 2003-2004 for the company S.C. OIL TEMINAL S.A.

	2003					2004				
	taken		discharged			taken		discharged		
	RAJA	wells	RAJA	APC	Marea Neagră	RAJA	Puţuri	RAJA	APC	Marea Neagră
Ian	33.995	1-500	10.075	-	-	20.533	11.316	18.855	4.039	8.955
Feb	25.617	1.350	-	-	-	25.900	1.483	9.716	4.432	13.235
Mar	21.006	14.135	19.135	3.500	12.411	18.736	2.924	11.157	4.225	6.278
Trim I	*80.618*	*16.985*	*29.210*	*3.500*	*12.411*	*80.892*	*15.723*	*39.728*	*12.696*	*28.468*
Apr	18.246	3.600	8.940	2.493	10.413	14.395	14.048	22.648	2.321	3.474
Mai	19.486	9.121	13.189	1.686	4.602	14.970	9.416	17.647	2.211	4.528

	2003					2004				
	taken		discharged			taken		discharged		
	RAJA	**wells**	**RAJA**	**APC**	**Marea Neagră**	**RAJA**	**Puţuri**	**RAJA**	**APC**	**Marea Neagră**
Iun	20.573	5.639	11.545	1.274	4.753	10.102	2.000	6.225	2.321	3.556
Trim II	*58.305*	*18.360*	*33.674*	*5.453*	*19.768*	*64.931*	*25.464*	*46.520*	*6.853*	*11.558*
Iul	13.832	9.278	15.278	2.597	5.235	-	-	-	-	-
Aug	31.710	14.417	25.939	2.278	3.490	-	-	-	-	-
Sept	11.414	6.644	13.677	1.752	2.579	-	-	-	-	-
Trim III	*56.956*	*30.339*	*54.894*	*6.627*	*11.304*	-	-	-	-	-

	2003					2004				
	taken		discharged			taken		discharged		
	RAJA	wells	RAJA	APC	Marea Neagră	RAJA	Puţuri	RAJA	APC	Marea Neagră
Oct	12.975	12.015	20.334	1.831	2.825	-	-	-	-	-
Noi	13.008	2.273	9.419	3.074	2.788	-	-	-	-	-
Dec	12.908	6.728	13.174	1.078	5.384	-	-	-	-	-
Trim IV	*38.891*	*21.016*	*42.927*	*5.983*	*10.997*	-	-	-	-	-
Total	**234.770**	**86.700**	**160.705**	**21.563**	**54.480**	-	-	-	-	-

Table 6. Quality indicators of discharged wastewater

Quality indicator	U.M.	Limit value	Measured value							
			2003			2004				
			oct	nov	dec	ian	feb	mar	apr	mai
Evacuare canalizare RAJA										
pH	unit.	6,5-8,5	7-7,5	7-7,5	7,5	7-7,5	7,5-8	7,5	7-7,5	
MTS	mg/l	350	56,7	44,5	61,8	0,1	0,07	0,07	0,067	
SET	mg/l	30	23,28	24,19	20,11	22,17	24,39	20,73	19,43	
CCO-Cr	mg/l	500	159,2	159	145,6	49,6	53,4	51,2	47,5	
Sulfuri	mg/l	1	0,07	0,04	0,04	164,83	171,44	160,6	150,86	
Detergent.	mg/l	25	0,09	0,07	0,06	0,05	0,05	0,049	0,048	
CBO_5	mg/l	300	151,2	144,47	145,21	135,92	156,5	139,2	124,71	
Evacuation Black Sea										
pH	unit.	6,5-8,5	5-8,5	5-8,5	5-8,5	5-8	5	5-8,5	8,5	60

Quality indicator	U.M.	Limit value	Measured value							
			2003			2004				
			oct	nov	dec	ian	feb	mar	apr	mai
MTS	mg/l	60	131,83	144,28	184,71	17,4	18,2	107,72	16,2	29,7
SET	mg/l	20	49,91	52,97	99,81	32,9	35,1	227,6 6	33,2	15,6
CCO-Cr	mg/l	125	337,1 2	335,9 5	673	119	113	753	118	114
Sulfuri	mg/l	0,5	0,24	0,19	0,48	20,3	20,4	130,19	20,2	0,04
Detergen t.	mg/l	0,5	0,3	0,24	0,65	0,08	0,08	0,63	0,07	0,06
Fenoli	mg/l	0,3	0,61	0,6	1,09	0,09	0,05	0,35	0,05	0,16
CBO5	mg/l	25	56,88	57,92	115,63	0,21	0,22	1,38	0,21	20,1
Prod. petr.	mg/l	5	11,0 1	12,1 3	22,1 2	4,34	4,49	28,7	4,43	4,4
APC sewer drain										
pH	unit.	6,5-8,5	9,5	5-9	8,5	5-8,5	4	0-9,0	5	

Quality indicator	U.M.	Limit value	Measured value							
			2003			2004				
			oct	nov	dec	ian	feb	mar	apr	mai
MTS	mg/l	350	277,8	109	186,1	79,7	82,5	19,5	17,2	
SET	mg/l	30	22,9	22	20,7	25,2	22,1	75	75,3	
CCO-Cr	mg/l	500	183	192	180	174	165	155	147	
Sulfuri	mg/l	1	0,1125	0,13	0,175	0,11	0,117	146,4	128,9	
Detergent.	mg/l	25	0,1713	0,105	0,1	0,12	0,114	0,08	0,09	
CBO5	mg/l	300	133,3	105	98,3	127,6	180,8	0,055	0,07	

With few exceptions, the required quality indicators are observed, without constant exceedances but only accidental ones.
SC OIL TERMINAL S.A. is concerned with improving the wastewater treatment process in the treatment plants of the three landfills, for which in 1991 and 1995 environmental impact studies were carried out at the PORT Landfill, together with the Institute for Environmental Research and Engineering (ICIM) Bucharest, following which solutions were proposed for the extension of the chemical and biological treatment plant.
Also in 1998, the Research Institute for Wastewater Treatment (ICPEAR) Bucharest, commissioned by IWACO BV Netherlands, within the project for "Development of the Port of Constanta - improving waste management", monitored the operation of the oil separator - from the PORT Warehouse , with the aim of implementing modern technologies for wastewater treatment and removal of the obligations of the

Convention (MARPOL 73/78) for the Prevention of Pollution Generated by Ships.
The study showed that the separator of petroleum products registers exceedances to a series of indicators - phenols, CCO, Cr, CBO5 and it is necessary to complete the current treatment scheme with a chemical treatment step.
SC OIL TERMINAL S.A. carried out a feasibility study on the modernization of the treatment plant in the PORT Warehouse by supplementing it with the chemical and biological stage.
The study was prepared by S.C. IPTANA S.A. in collaboration with ICPEAR Bucharest, through the contract CC 1061/1999.
The action is part of the greening program of the Port of Constanta.
Atmospheric emissions
The emissions generated by the activities carried out within the company can be grouped as follows:
o Basic activity emissions;
o Mechanical processing workshop emissions: suspended particles with metal content;
o Painting: VOC;
o Wood processing: suspended particles;
a PECO Station;
o Mobile sources.

Basic activity
The core business of OTC includes the following processes:
• Receipt / delivery of products:
- from / to sea and river vessels;
- from / in railway tank wagons;
- from / in transport pipelines;
- in tank trucks.
• Product circulation:
- from the means of transport to the storage tank;
- from the storage tank to the means of transport;
- from one tank to another storage tank;
- from one means of transport to another means of transport (from C.F. tanks to ships and vice versa), direct transhipment.
• Product storage:
- in above-ground, cylindrical, vertical metal tanks with fixed or floating lid.
• Product conditioning:
- heating the products to be brought under conditions of normal fluidity (pumpability).

The characteristic pollutants of these sources are volatile organic compounds (VOCs). The main substances found in the structure of these compounds resulting from the evaporation of fuels are (according to the Guidebook of Atmospheric Pollutants Inventory, EEA, 1998):

- 1% propane
- n-butane 20%
- 10% i-butane
- n-pentane 15%
- i-pentane 25%
- hexane 15%
- heptane 2%
- i-butene 1%
- 2-butene 2%
- 1-pentene 2%
- 2-pentene 3%
- 1.3 hexene 1.5%
- 1% benzene
- 1% toluene
- m, p-xylene 0.5%

It is found that the group of benzene-toluene-xylene substances is found, on average, in a proportion of 2.5% in the amount of VOCs emitted.

In the assessment of atmospheric emissions we started from the situation of 2003:

Table 7. Quantities of substances / raw materials transported by SC OIL TERMINAL S.A. at the level of 2003

Product	**receipt**	**deliveries**
	kg	**kg**
OIL	4.981.545.694	4.845.499.775
BENZINE	1.359.002.679	1.331.439.751
DIESEL	1.363.346.487	1,374.668.313
TAR	837.566.046	771.289.250
OIL REACTOR	10.247.111	12.172.107
I.F.O.	0	27.783.320
OILS	3.526.000	3.469.779
LIQUID CHEMISTRY	1.134.108.891	1.106.498.259

To evaluate the maximum momentary concentrations, the currently existing capacities were used:

- shuttle unloading capacity on ramps: 31,810 t / 24h;
- tank loading capacity C.F .: 20,880 t / 24h;
- unloading / loading capacity of ships: 21,000 m^3 / h;
- loading capacity in car tanks: 920 m^3 / day;

Regarding the calculation of VOC emissions into the atmosphere, we specify that in this type of activity the emissions take place as follows:

•upload download;
• storage;
•transport.

Upload - download.

There are several methods in the world to perform these operations:

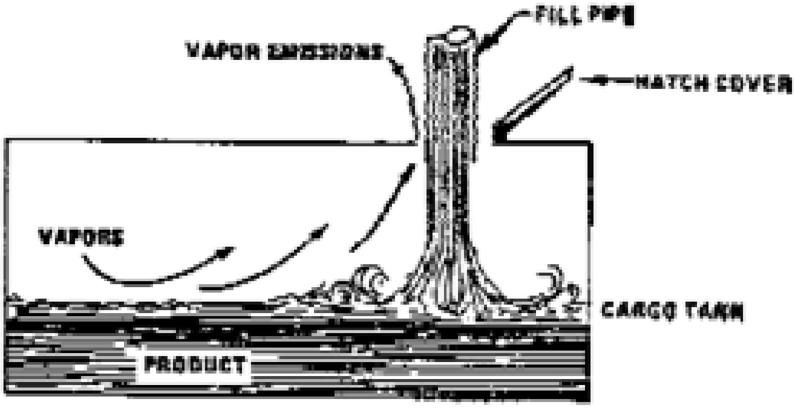


FIG. 1. Splash loading method

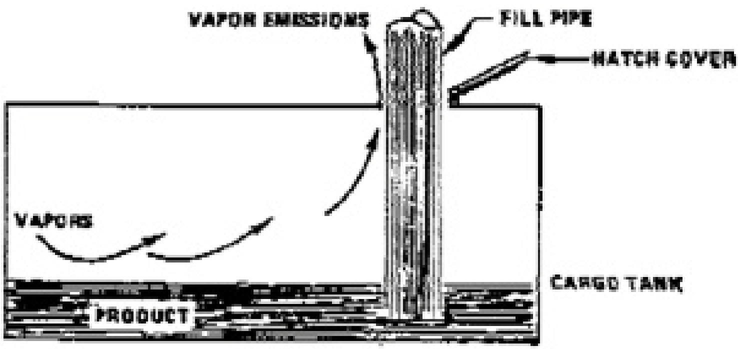


FIG. 2. Submerged filling pipes

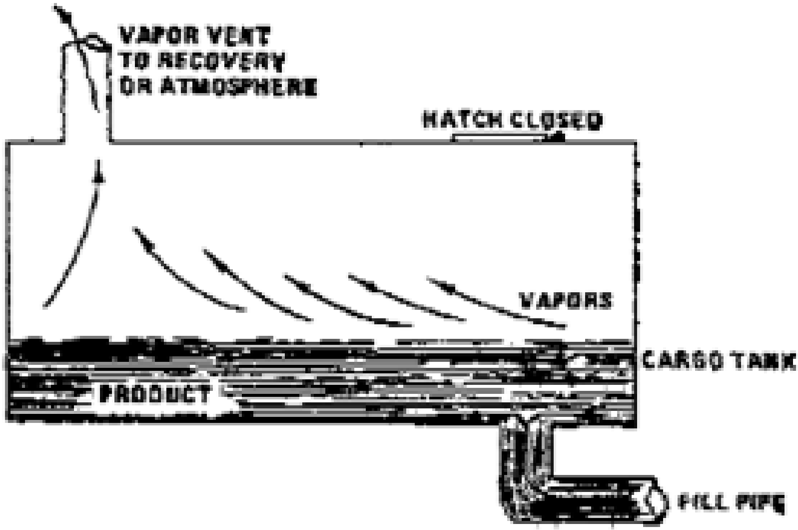


FIG. 3. Bottom loading

Recommendations for the loading system (also valid for CF or naval):

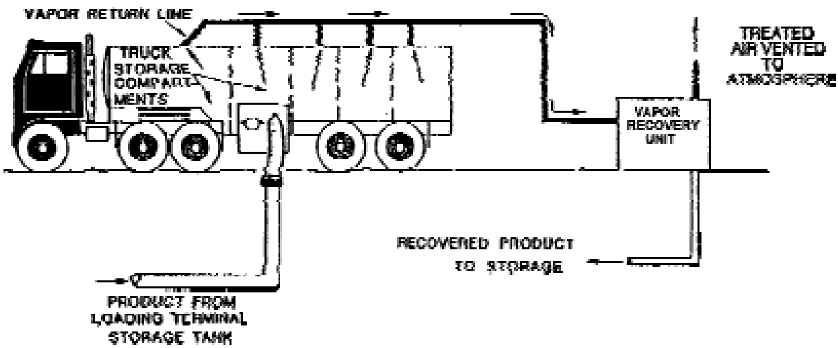


FIG. 4. Loading tank truck with vapor recovery

The emission factors depend fundamentally on the type of loading - discharge used (it is clear that the worst system - with the highest atmospheric emissions - is the one by "spraying" - about 3 times higher emissions), the type of liquid (gasoline, diesel, crude oil, fuel oil), liquid temperature, vapor pressure, saturation, etc. In the case of vapor recovery systems, emissions are more than 10 times lower.

Storage

It depends on the type of fuel stored and the temperature. It is the one exemplified at the storage of fuel in the PECO station.

Transport

The emission factors are between 0 and 1 mg / l transported. In extreme situations the factor goes up to 9 mg / l transported.

Table 8. VOC (HC) emissions (t / year)

Source of emission	**benzine**	**diesel fuel**	**oil**	**tar**	**oil**	**liquid chemicals**
Loading	1.457.530	1.390.613	0.149	461.499	0.039	816.558
Discharge	1.427.969	1.402.162	0.145	424.980	0.046	796.679
Transit	1.009	1.164	-	-	-	-
storage	242.140	279.278	-	-	-	-
Total	3.128.648	3.073.216	0.295	886.479	0.085	1.613.237
TOTAL (emissions / year)	8.701.961					

H.G. 568/2001: 0.01% of the total volume of "petrol" circulated is: 1,688,678 t / year.

Substantial exceedances of H.G. 568/2001. The company must, by 2007, comply with the provisions of this decision.

From which

• benzene: 48.5 t / an

• toluene: 1.4 kg / h

The emission calculations were made as follows:

• for VOCs (HC) and benzene: annual emissions (necessary for comparison with H.G. 568/2001)

• for toluene: short-term emissions (1 hour) - required in the modeling part for comparison with the limit value for population protection recommended by the World Health Organization for toluene - 1,000 □g / m3

We mention that the sources are not directed and as such the emissions cannot be regulated by Ord. 462/93

Emissions workshop mechanical processing, forging and heat treatment, painting, woodworking
In these situations, points 2 - 5, only qualitative estimates can be made (regarding the nature of the pollutants) - in the absence of concrete information on the quantities of materials processed within each section.

PECO station
The mass VOC flows emitted into the atmosphere are:
Maximum mass flow rate from fuel storage:
D1 = (0.12 kg / m3 / day x 128 m3 / 24h) = 0.39 kg / h
Average mass flow from motor vehicles:
D2 = (1.4 kg / m3 x 14 m3 / 24h) = 0.82 kg / h
Maximum mass flow when filling tanks:
D3 = (0.88 kg / m3 x 14 m3 / tranche) = 12.32 kg / tranche
It follows that, except for the time intervals in which the station is refueled, the mass VOC flow can reach the maximum value of:
D1 + D2 = 0.39 kg / h + 0.82 kg / h = 1.21 kg / h
During the time intervals in which the tanks are filled, the VOC emissions will be due only to this activity, because the distribution activity stops.
The mass flows of special organic pollutants from the VOC composition, emissions into the atmosphere are:

- Benzene - 8.2 g / h from distribution and 123.2 g / tranche from supply;
- Toluene - 3.9 g / h from storage, 8.2 g / h from distribution and 123.2 g / tranche from supply;
- Xylene - 1.9 g / h from storage, 4.1 g / h from distribution and 61.6 g / tranche from supply.

It is recommended to equip the station with vapor recovery systems, as in the figure below:

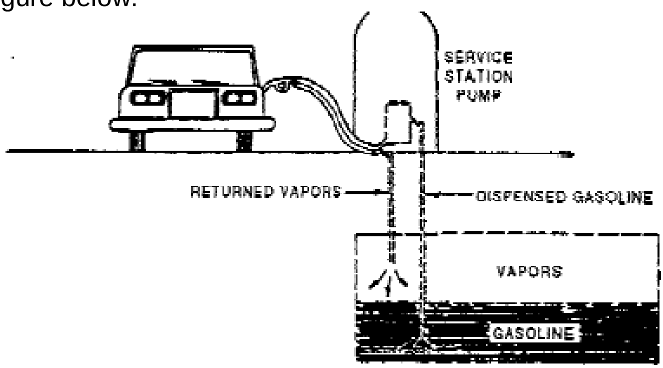


FIG. 5. Car fuel vapor recovery system

The same recommendation applies to refueling the station.

Mobile sources

Annual consumption (2003):
Gasoline = 79.55 t / year
Diesel = 416.68 t / year
Table no. 2.9.9
Mobile sources

Source name	Mass pollutants and flows [kg/day]											
	NO_x	CH_4	COV_{tot}	CO	N_2O	SO_2	CO_2	Cd	Cu	Cr	Ni	Se	Zn
Tansport	0.4	.4	.8	7.6	.0	.6	112.4	,00001	,0022	,00007	,00001	,00002	,001

Air pollution forecasting

The prediction of the ambient air pollution levels generated by all the sources related to the studied objective was performed by mathematical modeling of the concentration fields.

The evaluation of the concentration levels was performed by referring to the limit values provided by the regulations in force: OM 592/2002 and STAS 12574/1987.

Model description

CLIMATOLOGICAL model Martin and Tikvart, is a model for estimating long-term mediation concentrations of mediation for continuous point or surface sources. The fundamental physical basis of the model is the assumption that the spatial distribution of concentrations is given by the Gaussian formula of the feather.

The average concentration of AC in a receiver located at a distance from a surface source and at ground level z is given by the relation:

$$\overline{C}_A = \frac{16}{\pi}\int_0^\infty \left[\sum_{k=1}^{16} q_k(\rho) \sum_{l=1}^{8} \sum_{m=1}^{7} \Phi(k,l,m) S(\rho,z;u_l,P_m) \right] d\rho$$

where: k = index for the wind direction sector;

$q_k(\rho) = \int Q(\rho,\theta)d\theta$

for sector k;

Q(ρ,θ) =

emission in the unit of time of the surface source;

ρ = receiver distance for an infinitesimal surface source;

θ = angle in polar coordinates centered on the receiver;

l = index for wind speed class;

m = index for the stability class;

Φ (k, l, m) = frequency function of meteorological states;

S (ρ, z; Ul, Pm) = the function that defines the dispersion;

z = height of the receiver above the ground;

ul = representative wind speed;

Pm = stability class.

For point sources, the average CP concentration due to “n” sources, is given by the relation:

$$\overline{C}_P = \frac{16}{2\pi}\sum_{n=1}^{N}\sum_{l=1}^{8}\sum_{m=1}^{7}\frac{\Phi(k_n, l, m)\,G_n\,S(\rho_n, z; u_l, P_m)}{\rho_n}$$

where: kn = wind sector to no source;

Gn = emission for source n;

ρn = receiver distance of source n.

$$S(\rho,0;u_l,P_m) = \frac{2}{\sqrt{2\pi}u_l\,\sigma_z(\rho)}\exp\left(-\frac{1}{2}\left(\frac{h+\Delta h}{\sigma_z(\rho)}\right)^2\right)\exp\left(-\frac{0.692\rho}{u_l\,T_{1/2}}\right)$$

If the receiver is on the ground (respiratory level), then z = 0 and the form of the function S (ρ, z; ul, Pm) will be:
if σ_z (ρ) <0.8 L
and

$$S(\rho,0;u_l,P_m)=\frac{1}{u_l L}\exp\left(-\frac{0.692\rho}{u_l T_{1/2}}\right)\exp\left(-\frac{1}{2}\left(\frac{h+\Delta h}{\sigma_z(\rho)}\right)^2\right)$$

if σ_z (ρ) > 0.8 L
where: σ_z (ρ) = vertical scattering function;
h = source height;
Δh = pollutant feather elevation, calculated with Briggs relations;
L = mixture height;
T1 / 2 = half time of the pollutant.
The possibility of the disappearance of the pollutant by physical or chemical processes is given by the expression:
exp (-0,692ρ / ul T1 / 2)
The total concentration for a mediation period is the sum of the concentrations due to all sources for that period.
Input data includes information on:
• calculation grid;
• emission data;
• meteorological parameters.
Calculation grid - The model allows the calculation of the average concentration of the pollutant at any point at certain distances from the source / sources, by taking into account the contribution of all sources.
As a result, it is possible to calculate the concentrations on an area around the source. For this purpose, the area of interest is limited, and on its surface is fixed a grid, usually square, whose nodes constitute the receivers.
The number of nodes and the step of the grid are chosen according to the characteristics of the source, the area of interest and the problem to be answered.
The grid will have an origin and a coordinate system with the Ox axis to the east and the Oy axis to the north, depending on which the coordinates of the sources and nodes are established.
The emission data include the characteristics of the sources: the concentrations of the discharged pollutants, the geometric height, the diameter or surface of the emission, the speed and temperature of the evacuation of the pollutants.
Meteorological parameters are introduced in the form of the frequency function F (k, l, m) of the triplet wind direction, wind speed class and stability class, established on long series of data (multi-year). For example, if working on 16 wind sectors, 8 speed classes and 7 stability classes, the value table of the frequency function comprises 896 inputs.

The calculations were made in a grid with dimensions of 5 km x 4 km with a pitch of 25 m for the main characteristic pollutants emitted by the studied objective.
The dispersion program was run with the emission data determined in the emissions inventory in case of nominal capacity operation.
Multiannual meteorological data from Constanţa Meteorological Station were used. The ambient air concentrations were calculated for the representative pollutants emitted by the stationary and mobile sources related to the objective: VOCtot, Benzene and Toluene
The results of the dispersion calculations, respectively the maximum concentrations of pollutants at ground level (including the distance from the source / site limit) are presented in comparison with the limit values and, as the case may be, with the alert thresholds, according to the environmental legislation in force in Tables 10., 11. and in the form of Isoconcentration Maps (Figures 6,7, 8).

Table 10. Maximum concentrations at different mediation intervals

a. Short / medium intervals (1 hour)

pollutant	**Maximum concentration**			**Obs.**
	C_{max} [µg/m^3]	**Alert threshold (PA) [µg/m^3]**	**Limit value (VL) = intervention threshold [µg/m^3]**	
1.	**2.**	**3.**	**4.**	**5.**
Toluene	450	-	1,000*	< VL;

(*)VL recomandated by OMS

b. Long mediation intervals (year)

Pollutant	**Maximum concentration**			**Obs.**
	C_{max} [µg/m^3]	**Alert threshold [µg/m^3]**	**Limit value (VL) = intervention threshold [µg/m^3]**	
1.	**2.**	**3.**	**4.**	**5.**
Benzen	14.5	-	10(1)	> VL
COV_{tot}	2.200	-	-	-

(1) VL + Tolerance margin until 01.01.2007 (5 + 5)

It is mentioned that OM 592/2002 and STAS 12574/1987 do not provide limit values for VOCtot nor for the compounds in the VOCtot structure that will be emitted from the objective site except for benzene.

Table 11. Comparison between maximum concentrations and limit values

a. Short and medium mediation intervals (1 hour) Toluene

Distance from the source / limit of the platform perimeter and sector (m - sector)	Concentration / beach concentrations [μg/m³]	Health alert threshold (PA) [μg/m³]	Limit value = Health intervention threshold (VL/PI) [μg/m³]	Protection limit value Vegetation (VLV) / ecosystems [μg/m³]	Obs.
1.	**2.**	**3.**	**4.**	**5.**	**6.**
0-250 - all directions	450-100	-	1.000*	-	< VL;

(*)VL recomandated by OMS

b. Long mediation intervals

Benzene

Distance from the source / limit of the platform perimeter and sector (m - sector)	Concentration / beach concentrations [μg/m³]	Health alert threshold (PA) [μg/m³]	Limit value = Health intervention threshold (VL/PI) [μg/m³]	Protection limit value Vegetation (VLV) / ecosystems [μg/m³]	Obs,
1.	**2.**	**3.**	**4.**	**5.**	**6.**
0-350 N, E	15-5	-	10(1)	-	< VL
0-450 E	15-3				< VL
0-875 S	15-1				< VL

VL + Tolerance margin until 01.01.2007

COV_{tot}

Distance from the source / limit of the platform perimeter and sector (m - sector)	Concentration / beach concentrations [$\mu g/m^3$]	Health alert threshold (PA) [$\mu g/m^3$]	Limit value = Health intervention threshold (VL/PI) [$\mu g/m^3$]	Protection limit value Vegetation (VLV) / ecosystems [$\mu g/m^3$]	Obs.
1.	**2.**	**3.**	**4.**	**5.**	**6.**
0-350 N, E	2.200-1.000	-	-	-	< VL
0-500 E	2.200-500				< VL
0-1250 S	2.200-100				< VL

The analysis of the results obtained following the mathematical modeling of the dispersion of pollutants in the atmosphere compared to the limit values for the concentrations of pollutants in the atmosphere (immissions), provided by the legislation in force highlights that the levels of concentrations in ambient air generated by the sources will be below the limit values, except for benzene.

Due to the fact that the sources are low, without high evacuation speeds and with the temperature equal to the ambient one, the highest concentration values will be registered near the sources, outside the premises the values being much lower, even for benzene - decreasing to 3 - 5 /g / m^3.

The sensitive receptors in the area are the population and the vegetation. The concentrations of pollutants in the area of maximum influence of the objective, outside its perimeter, are below the limit values for the protection of receptors, both by the singular contribution of the objective sources and by the cumulated contribution with the influence of the existing sources in the area. In particular, it is noted that the olfactory threshold for hydrocarbons specific to the handling and storage of fuels of 6,000 μg / m^3 will not be reached or exceeded.

Impact mitigation measures

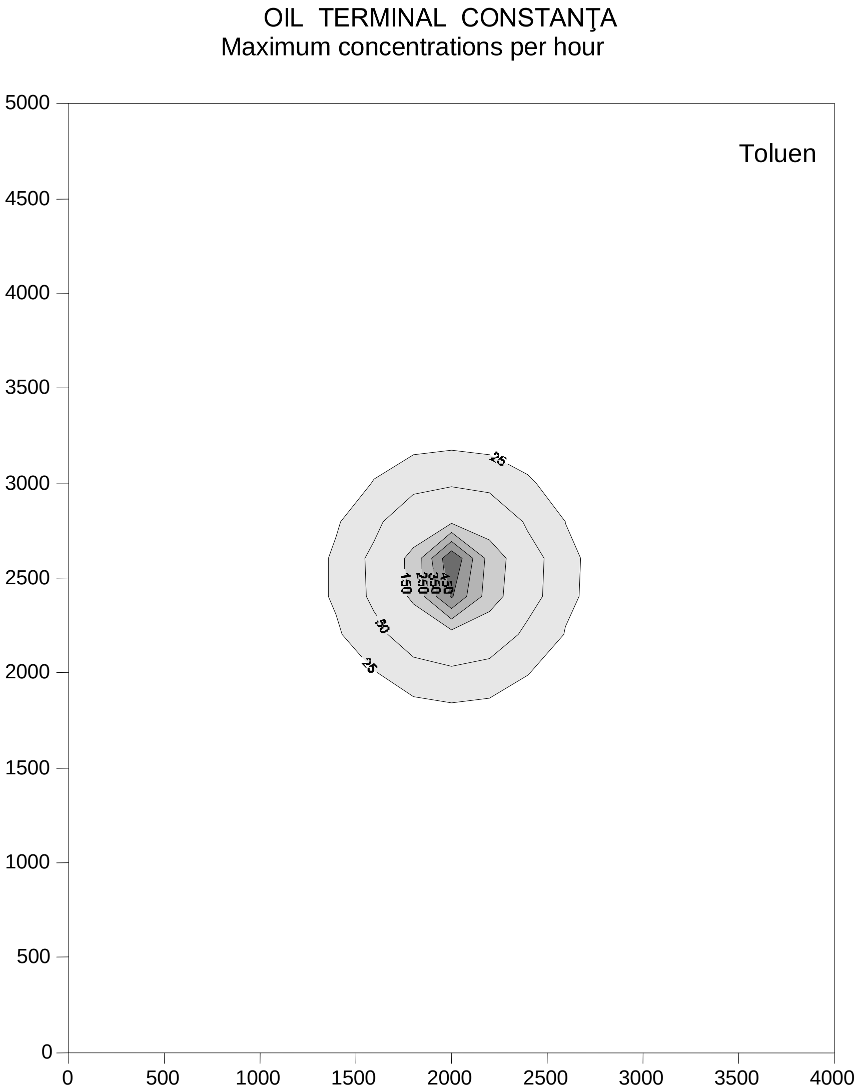


Figure 6 Toluene isoconcentration map

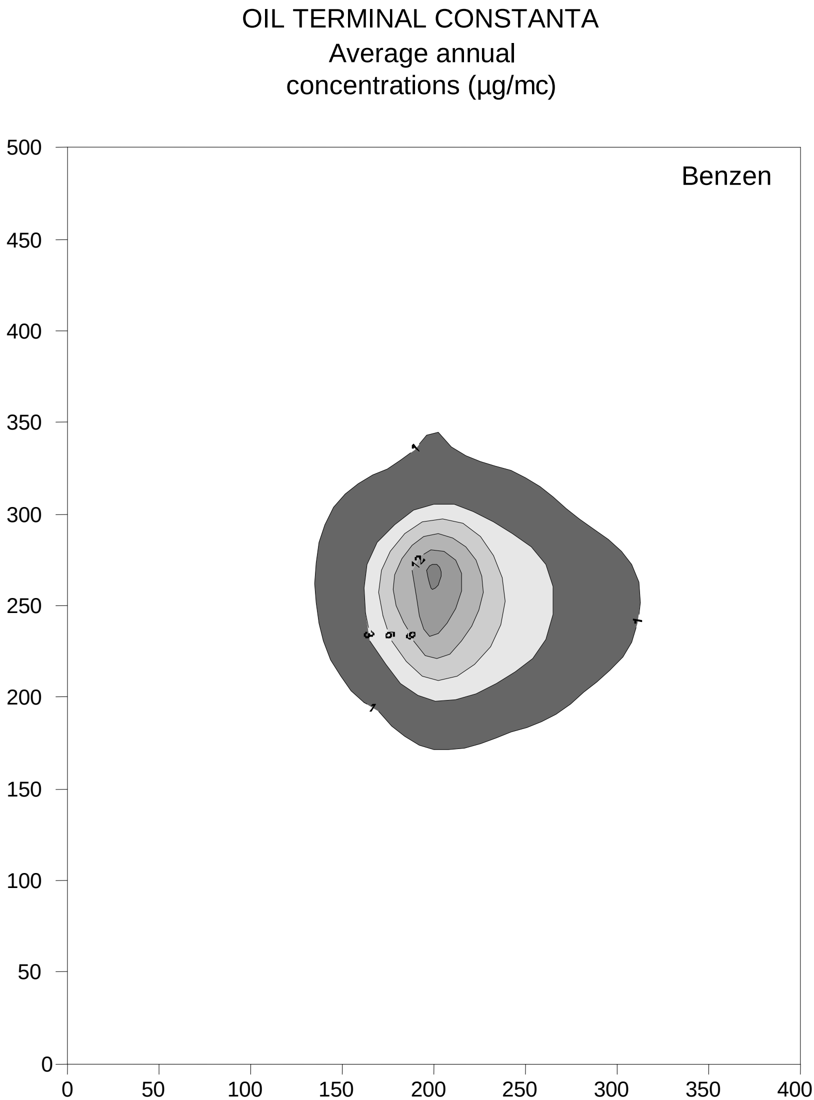


Figure 7. Benzene isoconcentration map

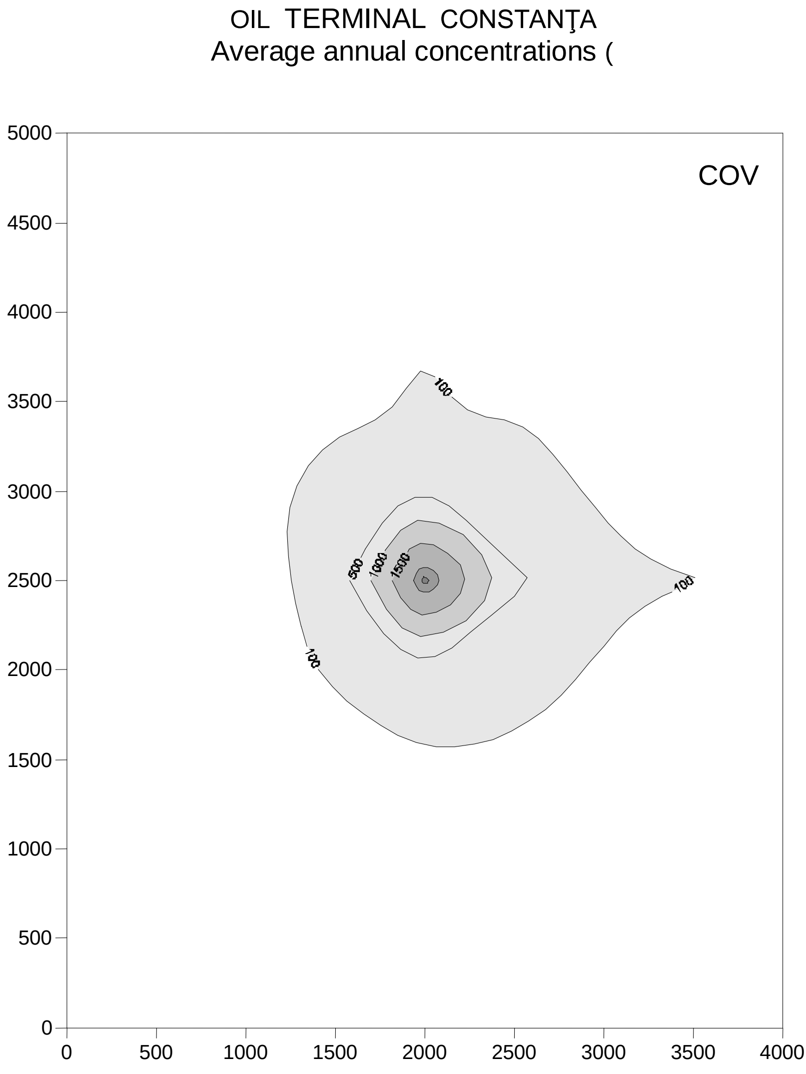


Figure 8. VOC isoconcentration map

The impact of noise

In accordance with STAS 10009 - 88 URBAN ACOUSTICS the deposits from the composition of S.C. OIL TERMINAL S.A. Constanţa falls into the following location categories.

The NORD warehouse consists of the NORD I warehouse, which also houses the company's administrative headquarters and the NORD II warehouse.

On the east side, the NORD depot borders the urban area of Constanţa municipality, and on the west, north and south sides - with industrial areas.

The PORT warehouse is not a source of noise and vibration for neighbors in the area.

Given that the PORT Warehouse covers an area of approx. 30 ha, the influence of the noise generated by the pump houses - an important source of noise - is not felt.

The PORT warehouse is surrounded by industrial areas on the east and north sides and agricultural areas on the west and south sides.

The SUD warehouse is adjacent to the Constanţa-Mangalia national road - considered the main technical category I street and the Constanţa-Mangalia railway - the railway area.

On the north and south sides it borders the port of Constanţa (ore and south-Agigea), and on the east side is the Black Sea coast.

The three depots are considered as industrial enclosures, whose equivalent noise level does not exceed 65 dB (A), measured at the enclosure limit.

Regarding the impact of noise on the work environment, in warehouses there are pump houses and the compressor house, which during operation cause noise.

The Inspectorate of Sanitary Police and Preventive Medicine Constanţa made determinations of the noise level inside the rooms where the pumps are installed and 10 m away from them, and determined levels of 82-87 dB (A), according to the bulletins of determination 457-477 of 18.06.1992. The maximum allowed level is 90 dB (A). The company takes permanent measures to improve working conditions for service personnel, considering noise as a risk factor. For the surrounding areas, the production activities of the three warehouses are not known as sources of noise and vibration that create discomfort.

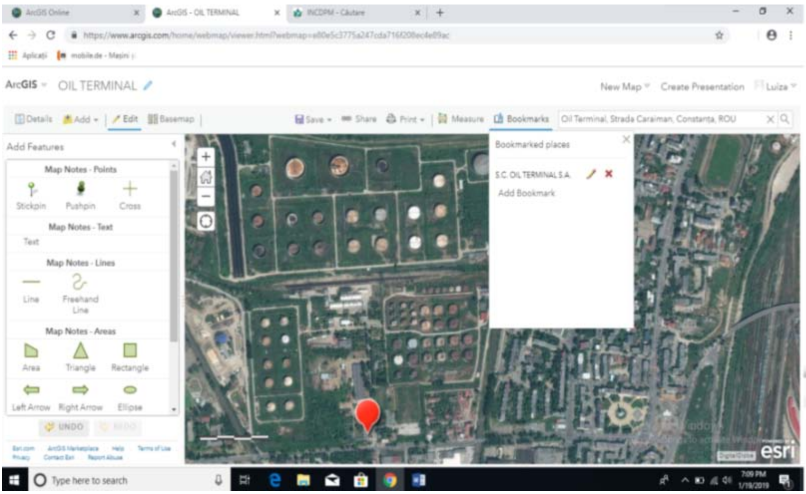
Proximity of voltage cables

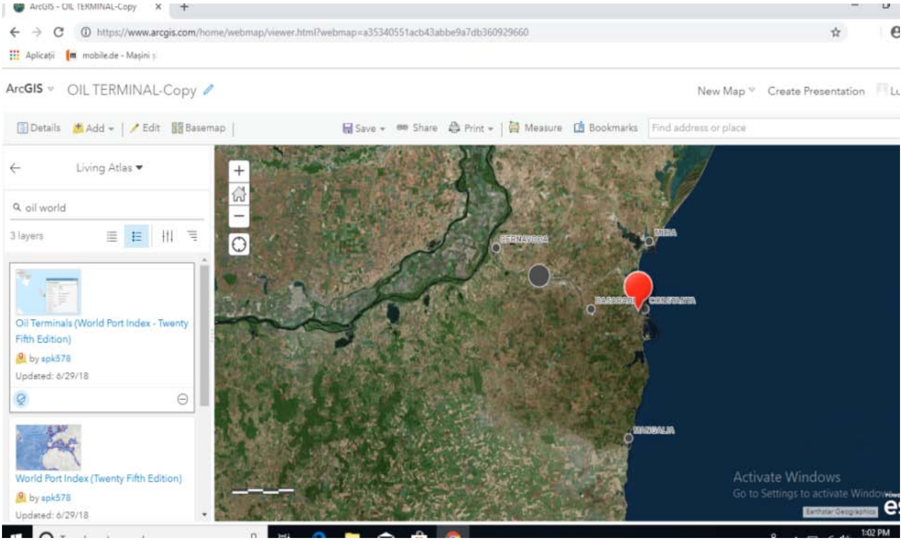
The electricity supply is made from the national energy system through the CONEL Constanţa Electric Networks Branch. SC OIL

TERMINAL S.A. has a contract for the delivery of electricity to large consumers with RENEL Constanţa, no. 35/26 September 1996.
Underground and / or surface high voltage cables can be found in the S.C. OIL TERMINAL S.A. only up to TRAFO stations, in CONEL operation.

Sources of information

The sources of information are represented by the documentation provided by the beneficiary, by contracts concluded with the service providers, of the studies carried out previously, as well as by the information gathered following the findings made on the spot.
ArcGIS applications:

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Oil Terminals (World Port Index - Twenty Fifth Edition)
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Updated: 6/29/18
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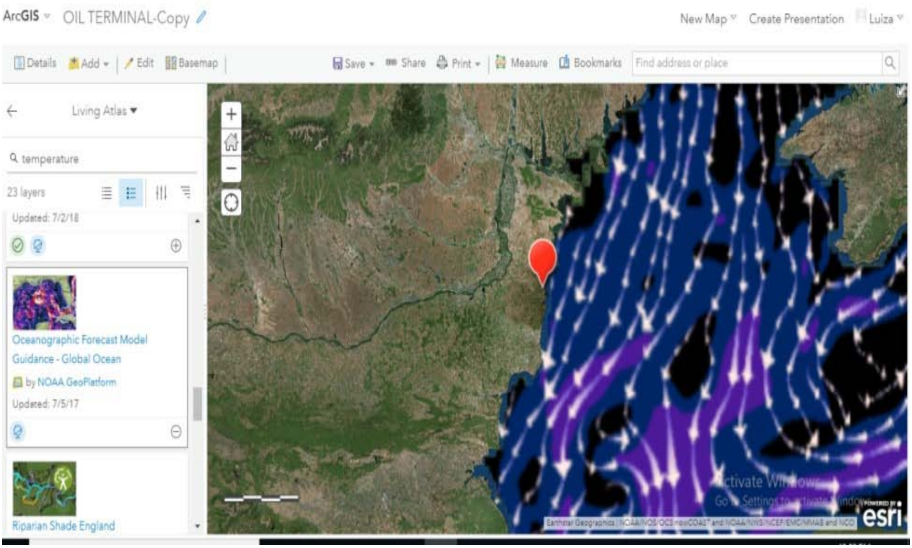
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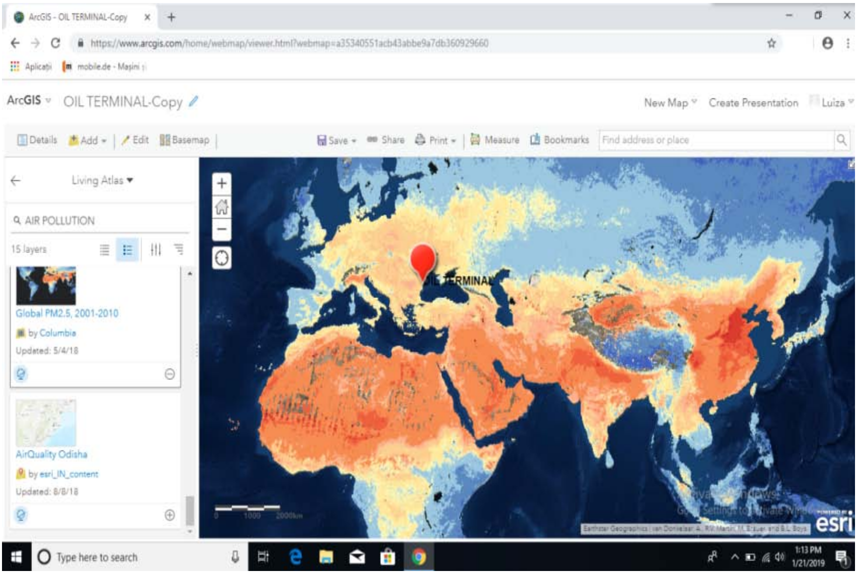
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AIR POLLUTION
15 layers
Global PM2.5, 2001-2010
by Columbia
Updated: 5/4/18
AirQuality Odisha
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Updated: 8/8/18
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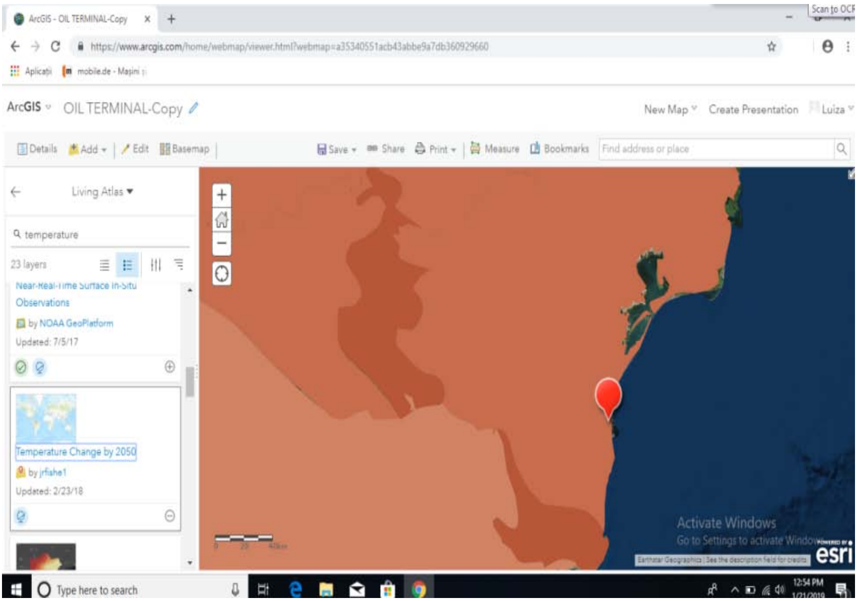
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