EU4Environment in Eastern Partner Countries:
Water Resources and Environmental Data (ENI/2021/425-550)

PROPOSAL OF A NATIONAL METHODOLOGY FOR THE ASSESSMENT OF THE HYDROMORPHOLOGICAL STATUS OF THE BLACK SEA COASTAL AND TRANSITIONAL WATER BODIES IN GEORGIA: PILOT AREA APPLICATION – POTI

Contract-No: 20940-Cl/GE-MG-2023/1-A1

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ABOUT THIS REPORT

AUTHORS

Mamuka GVILAVA, Coastal and Marine Management Expert, ICZM National Focal Point for Georgia

Zurab SAVANELI, Oceanographer, Institute of Oceanography and Hydrology, Tbilisi State University

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Umweltbundesamt GmbH	Office International de l'Eau (IOW)
Spittelauer Lände 5	21/23 rue de Madrid
1090 Vienna, Austria	75008 Paris, FRANCE

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ABOUT EU4ENVIRONMENT – WATER RESOURCES AND ENVIRONMENTAL DATA

This Programme aims at improving people's wellbeing in EU's Eastern Partner Countries and enabling their green transformation in line with the European Green Deal and the Sustainable Development Goals (SDGs). The programme's activities are clustered around two specific objectives: 1) support a more sustainable use of water resources and 2) improve the use of sound environmental data and their availability for policy-makers and citizens. It ensures continuity of the Shared Environmental Information System Phase II and the EU Water Initiative Plus for Eastern Partnership programmes.

The Programme is implemented by five Partner organisations: Environment Agency Austria (UBA), Austrian Development Agency (ADA), International Office for Water (OiEau) (France), Organisation for Economic Co-operation and Development (OECD), United Nations Economic Commission for Europe (UNECE). The action is co-funded by the European Union, the Austrian Development Cooperation and the French Artois-Picardie Water Agency based on a budget of EUR 12,75 million (EUR 12 million EU contribution). The implementation period is 2021-2024.

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List of abbreviations

ADA........................Austrian Development Agency
AWB.......................Artificial Water Body
BP ....British Petroleum
CTW ....Coastal and Transitional Waters
CW ....Coastal Waters
DSAS ....Digital Shoreline Analysis System
EU4EnvWD............EU4Environment in Eastern Partner Countries: Water Resources and Environmental Data
EUWI+...................European Union Water Initiative Plus
FIZ ....Free Industrial Zone
GE ....Country Code for Georgia
GFW ....Global Fishing Watch
HAI ....Hydromorphological Alteration Index
HMWB ....Heavily Modified Water Body
HQI.........................Hydromorphological Quality Index
HISWA...................HIndcast Shallow water Waves (TU-Delft model)
HYMO ....HydroMorphological
KNP ....Kolkheti National Park
MEPA ....Ministry of Environmental Protection and Agriculture of Georgia
MImAS ....Morphological Impact Assessment System tool
NEA ....National Environment Agency
PONTOS ....Copernicus assisted environmental monitoring across the Black Sea Basin project
SDGs......................Sustainable Development Goals
SLR ....Sea Level Rise
TW ....Transitional Waters
UBA.......................Umweltbundesamt GmbH, Environment Agency Austria
UNECE...................United Nations Economic Commission for Europe
UNIBEST-LT ....Wave-driven longshore sediment transport model (Deltares)
UNIBEST-TC...........Wave-driven cross-shore sediment transport model (Deltares)
USD ....United States Dollar
USGS ....United States Geological Survey
WFD ....Water Framework Directive
WGS ....World Geodetic System
WWTP...................Waste Water Treatment Plan

Executive Summary

This summary provides a condensed overview of the main results regarding the hydromorphological status and changes in the Poti coast, which serves as a pilot test area for the proposed national methodology.

The document applies the methodology for assessing the hydromorphological status and underlines the significance of incorporating quantitative data to derive accurate metrics. It emphasizes the need for applying hydromorphological monitoring methodologies and the importance of field-based data collection for comprehensive evaluations.

Drawing from the comprehensive report by Arcadis (2000), data and information provided by the National Environmental Agency (NEA), and coastal and marine earth observations datasets from global, regional, and national sources, the document presents an analysis of the hydromorphological status and coastal dynamics in Poti area. It focuses on sediment transport, erosion, accretion, protection scenarios, and climate change impacts, with implications for Coastal and Transitional Water bodies (CTWs). Despite data limitations, qualitative estimation of the Hydromorphological Quality Index (HQI) was found feasible, showcasing the applicability of the proposed methodology.

A recommendation is made for the National Environmental Agency to initiate a hydromorphological monitoring program focused on measuring all required quality elements. This is crucial for quantitatively deriving metrics required to calculate and map CTW HQI. Consideration was also given to delineating the Northern and Southern Channels of the Rioni River as Artificial Water Bodies or Heavily Modified Water Bodies for improved assessments.

In conclusion, the document serves as a guide for assessing and managing the hydromorphological status of CTWs in Georgia, offering specific insights into the Poti area. It underscores the importance of data-driven assessments, ongoing improvements in monitoring methodologies, and the development of adaptation plans to address emerging challenges. This includes the impact of climate change-driven sea-level rise, particularly affecting Poti and its surroundings. It can be concluded, that proposed national HYMO methodology has been successfully applied along the sections of the Poti pilot area.

1. Introduction

The document entitled the 'Proposal of a National Methodology for the Assessment of the Hydromorphological Status of Coastal and Transitional Water Bodies in Georgia'[1] (HYMO Methodology) was proposed for Georgia based on the requirements of the Water Framework Directive[2] and related guidance documents,[3, 4, 5] the provisions of the European Standard for the monitoring of Coastal and Transitional Water (CTW) bodies,[6] as well as the respective requirements of the Law of Georgia on Water Resources Management.[7]

Proposed HYMO Methodology specifies:

1. Methods for identifying and designating Heavily Modified (HMWB) & Artificial Water Bodies (AWB);

2. Basic typologies, reference conditions and classification systems;

3. Hydromorphological monitoring of CTW bodies;

4. General & specific considerations for monitoring hydromorphological quality elements of CTW bodies;

5. Tools and routines for the hydromorphological classification of Georgian Black Sea CTWs;

6. Requirements & availability of hydromorphological data, reference literature for assessing CTWs status;

7. Latest delineation of Georgian Black Sea CTWs annexed to the HYMO Methodology.[8]

In this document, the proposed HYMO method is applied to the pilot area of Poti and its applicability is tested for possible replication along the Black Sea coast of Georgia.

The specific tasks order for the elaboration of the document HYMO Guideline Pilot Area Application – Poti were defined as follows:

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[1] 'Proposal of a National Methodology for the Assessment of the Hydromorphological Status of Coastal and Transitional Water Bodies in Georgia', EU4Environment in Eastern Partner Countries: Water Resources and Environmental Data (ENI/2021/425-550), March, 2024.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02000L0060-20141120

[3] https://circabc.europa.eu/sd/a/f9b057f4-4a91-46a3-b69a-e23b4cada8ef/Guidance No 4 - heavily modified water bodies - HMWB (WG 2.2).pdf

[4] https://circabc.europa.eu/sd/a/85912f96-4dca-432e-84d6-a4dded785da5/Guidance No 5 - 0characterisation of coastal waters - COAST (WG 2.4).pdf

[5] https://circabc.europa.eu/sd/a/63f7715f-0f45-4955-b7cb-58ca305e42a8/Guidance No 7 - Monitoring (WG 2.7).pdf

[6] https://www.en-standard.eu/csn-en-17123-water-quality-guidance-on-determining-the-degree-of-modification-of-the-hydromorphological-features-of-transitional-and-coastal-waters

[7] https://matsne.gov.ge/ka/document/view/5846594?publication=0

[8] This delineation was initially produced in 2020 with the support of the EUWI+ project. As a result of 2 surveys from Kobuleti to Anaklia in 2022 and 2023, this delineation proposal was slightly improved for the area from Sarpi to Anaklia. The EU4Env Water and Data GE Delineation proposal will be presented in the document: "An improved delineation proposal of Georgia's Coastal and Transitional Waters, reference conditions and assessment of the ecological status of water bodies in the pilot area from Kobuleti to Anaklia". This report will be prepared in March 2024.

1. Implementation of one hydromorphological monitoring of coastline sections in the Poti pilot area (Figure 1) with photo documentation;

2. Assessment of the hydromorphological status for each coastline section, including identification of occurring HMWBs and/or AWBs (Table 1).

Figure 1. Location of Poti pilot area with indicated endpoints of HYMO coastline sections.

Table 1. Coordinates of the coastline section endpoints

Coastline sections in Poti pilot area	Endpoint	Geographic position (WGS 84)		Endpoint	Geographic position (WGS 84)	
		Latitude	Longitude		Latitude	Longitude
HYMO 01	H01	42.226096	41.634540	H02	42.212147	41.629275
HYMO 02	H03	42.208743	41.628874	H04	42.185566	41.634300
HYMO 03	H05	42.182564	41.636042	H06	42.160150	41.650384
HYMO 04	H06	42.160150	41.650384	H07	42.159907	41.645432
HYMO 05	H08	42.149378	41.653406	H09	42.131968	41.660132
HYMO 06	H10	42.133194	41.663002	H11	42.090717	41.700899
HYMO 07	H11	42.090717	41.700899	H12	42.098001	41.710932
HYMO 08	H12	42.098001	41.710932	H13	42.137568	41.693814
HYMO 09	H10	42.133194	41.663002	H14	42.185532	41.706162
HYMO 10	H03	42.208743	41.628874	H15	42.186764	41.706579

Note: Initial task order included HYMO 01-08 sections, while two more sections HYMO 09-10 were added as a result of the HYMO monitoring and assessment against historic baseline for Poti pilot area.

2. HYMO Baseline for Poti Area

This chapter describes HYMO baseline conditions in the Poti pilot area. Three main sources were used for compiling it. In the context of the prevailing conditions around year 2000, description is based on the comprehensive report referred to as Arcadis (2000), which is indeed the key resource.[9] Current conditions to assess the change are based on the data and information provided by National Environmental Agency of Georgia in response to respective request. Coastal and marine earth observations datasets from various global, regional and national sources are also used to analyse the changes in HYMO conditions.

The coastline of the Poti area

The report by Arcadis (2000)[9] sets an excellent baseline for the Poti pilot area and even beyond (coastal cells reaching mouths of the rivers Khobistskali to the north and Supsa to the south, latter referred to as 'Poti area', while urban parts are simply referred to as Poti). Most of the descriptions and findings of this report remain valid even today as this analysis spans forward modelling for 25 years. Some of these findings are validated in the context of the current situation, evaluating their relevance currently after forecast period almost passed. This chapter very closely follows Arcadis (2000).[9]

The coastline in Poti area is characterised by a sandy coast interrupted by the three mouths of the Rioni River (Figure 2). Due to changes in flow regime after 1939 large changes in the coastal system occurred.

The redirection of the Rioni river mouth. The beaches at Poti consist of relatively fine sand originating from the Rioni River. The port of Poti has been constructed in the period between 1863 and 1870. In that period the Rioni river flowed through the city of Poti to the sea and debouched into the sea via the so-called South Channel, which is located at a distance of 2 km south of the port. The river transported enough sediment to the sea to build up a delta in front of the city and south of the river mouth. This process of beach build-up at the mouth of South Channel lasted till 1939. The maximum protrusion of the river mouth into the Black Sea was in that time approximately 540 m.

In 1939 a short-cut channel was commissioned. This North Channel is located between the bifurcation point about 7 km upstream of the original river mouth and the sea north of the port. From that moment on the delta in front of the city started to retreat as a result of the reduced sediment discharge through the South Channel. At the new Rioni mouth, north of Poti, a delta was formed. Nowadays this delta extends till the Khobistskali river, approximately 15 km north of Poti (Figure 2, top).

There was no discharge of sediment through the South Channel from 1939 till 1959. This caused the delta of the South Channel to erode very fast. In 1959 the sluice works upstream of the Rioni River were finished and water was discharged through the South Channel again. The amount of sediment which was transported through the South Channel was however not sufficient to stop the erosion of the old Rioni delta. Figure 3 shows the erosion and accretion process of the Rioni deltas.

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[9] Arcadis (2000), Coastal Protection Study for Poti, Chapter 4 of IMWM Report, Georgia Integrated Coastal Management Project, SENTER, Arcadis Euroconsult/Alkyon/HKV Consultants/CDI, 2000.

The objectives of the study were to (i) analyse the existing coastal and river system; (ii) identify the erosion problems; (iii) define possible coastal protection scenarios which will protect the entire coastline of the study-area; (iv) assess the impact of those scenarios by using computer models; and (v) evaluate the protection scenarios by means of a cost-benefit analysis at prefeasibility level.

This report is related to the results of a coastal erosion study for the Poti area. The coastal and river system has been analysed by using computer models 2000-2025. Coastal protection scenarios have been defined and the impact of the scenarios on the coastal and river processes has been determined by using the calibrated computer models and engineering experience. A most promising protection scenario has been defined from both a morphological and economical point of view.

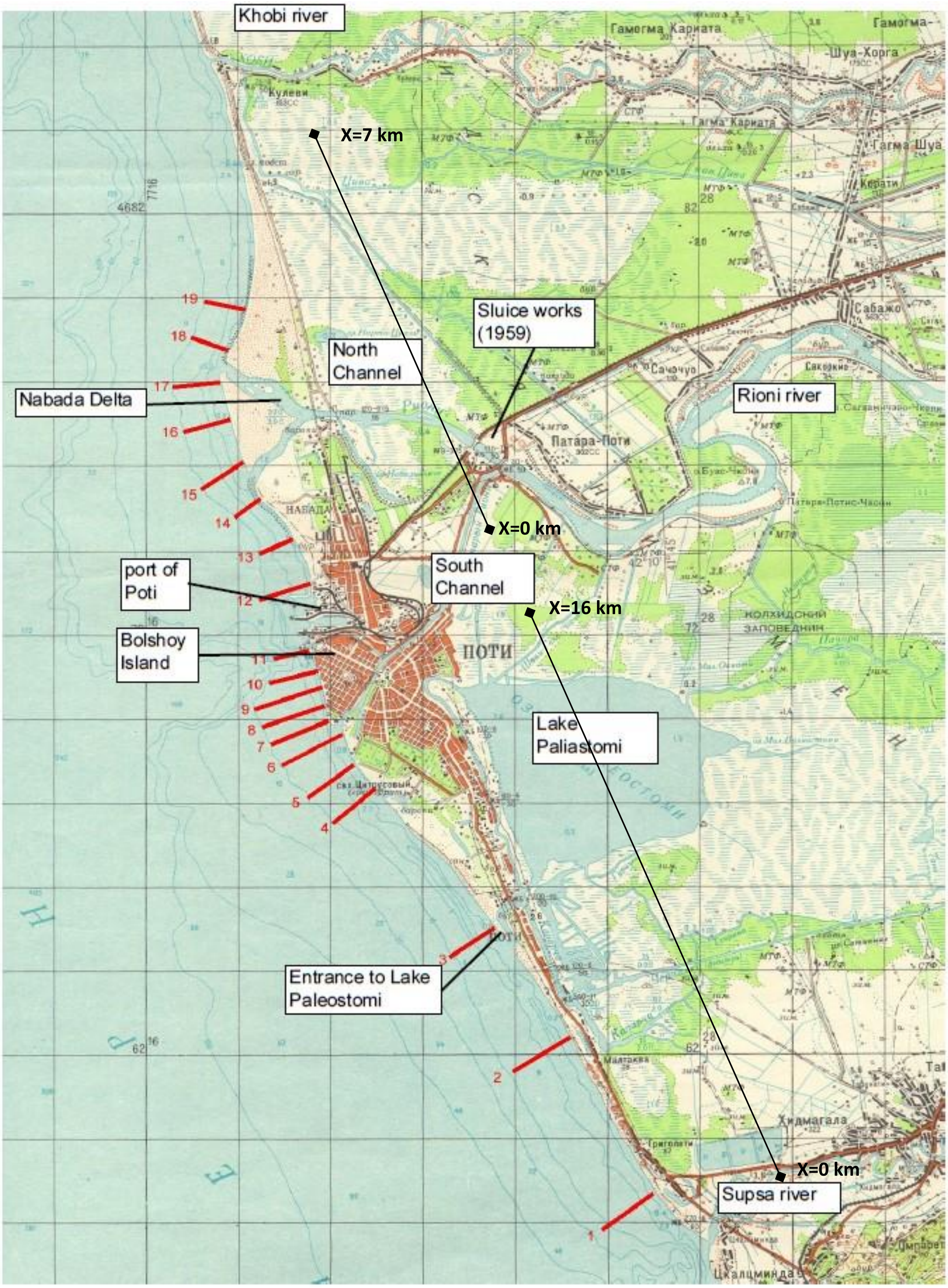


Figure 2. Poti area from Khobistskali to Supsa mouths, measured beach profiles, two reference lines.[9]

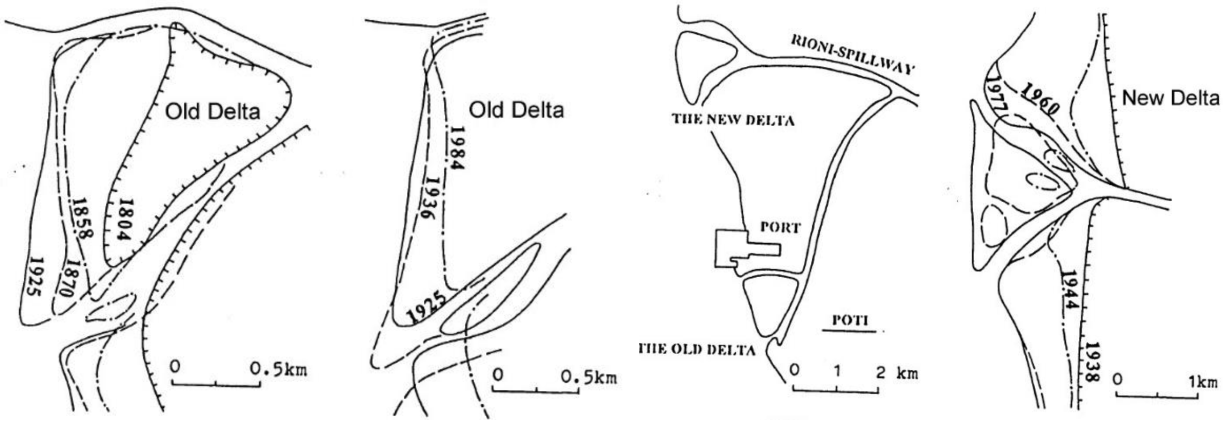


Figure 3. Erosion and accretion processes at the Rioni deltas north and south of the Poti port.[9]

The submarine canyon at Poti. Most large rivers along the eastern part of the Black Sea have a submarine canyon near their mouths. Poti also has a canyon close to the coastline where Rioni river flowed into the sea just south of the port. Canyon is present only a few hundred meters from the coastline.

Canyon currently seems stable, however, during the attempts of high discharges of sediment from the South Channel in 1959 and 1983 the canyon reportedly activated, moving in a very short period of time towards the coast over a distance of respectively 250 m and 150 m, caused by geotechnical instabilities due to rapid deposition of sediments due to longshore and cross-shore transport.

Attempts of stopping the erosion near the South Channel. Between 1983 and 1987 a test was done in order to create a larger discharge of water and sediment through the South Channel. The sluices to the South Channel were opened as far as possible in order to create a large discharge of water and sediments. The unsuccessful test was stopped in 1987 because the large discharge caused damage to the walls along the South Channel (scour).

From 1987 till 1990 approximately 2 x 10^6 m^3 of beach forming sand was nourished along the Didi Island, south of the port. Sand was taken from the Rioni River by using a small cutter dredger, transported to coastline through pipelines. Scheme was stopped because of the political situation and not resumed afterwards because of destruction of the system and financial restrictions. Nourished material along the Didi Island was again washed away.

In the late 1950s an attempt was made to protect the part of the coastline south of the South Channel with groynes. Those groynes consisted of rows of piles with rock in between. This type of groyne did not work properly and the erosion continued.

Between 1960 and 1970 a revetment of large stones was made along the coastline of the Didi island. This revetment is presently still protecting the coastline against erosion. However, profile measurements by Arcadis (2000)[9] showed, that the erosion still continued beneath the revetment.

Accretion near the Lake Paliastomi. Near the entrance to the Lake Paliastomi the coastline is accreting. This accreted material originates from the eroding delta in the South Channel (where sediment load decreased strongly since 1939), but erosion has however not yet reached the entrance of Lake Paliastomi and along that part of the coastline there was still accretion.

Some erosion near the Supsa river in the area north of the river mouth over a length of approximately 4 km is reported by Arcadis (2000)[9] as having no relationship with the erosion near the South Channel. In this area BP periodically dumped tens of thousands m^3 of gravel on sandy beach to protect its oil export pipeline and this practice was replicated by the Roads Department of Georgia in Grigoleti, albeit on larger scale dumping on 2 km section hundreds of thousands m^3 of gravel in 2016 & 2019, with strong opposition by local stakeholders complaining severe reduction of sandy beach quality & impact on summer tourism.

For three different years (1957, 1983 and 1999) the measured position of the coastline between the Supsa River and the Nabada Delta were available, shown in Figure 4.

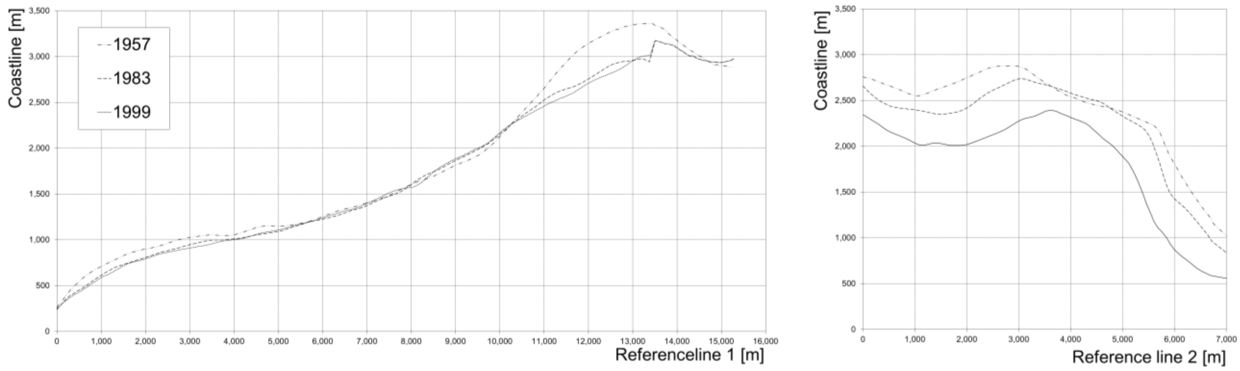


Figure 4. Coastline change north of Supsa river, near Lake Paliastomi, South Channel, New Delta.[9]

Just north of the Supsa River the coastline has eroded since 1957. Further to the north at approximately 4 to 5 km south of the South Channel there is still accretion due to the former delta of the South Channel. Just south of the South Channel the coastline has eroded with a rate of approximately 8 m/yr. Since 60's coastline of the Didi Island is fixed by a rock dump. No erosion has taken place along this coastline section. North of the Poti port coastline is still accreting with a rate of 20 to 25 m. Nabada Island has not accreted very much since 1983 till 1999. This could be caused by a smaller discharge of sediment from Rioni River.

Cross-shore profiles. Between 1979 and 1991 a number of cross-shore profiles were measured in the Poti area. Additional coastal profiles were recorded by Arcadis (2000).[9] The locations of the cross-shore profiles are summarised on Figure 2, while on Figure 5 profiles are given for various locations in Poti area.

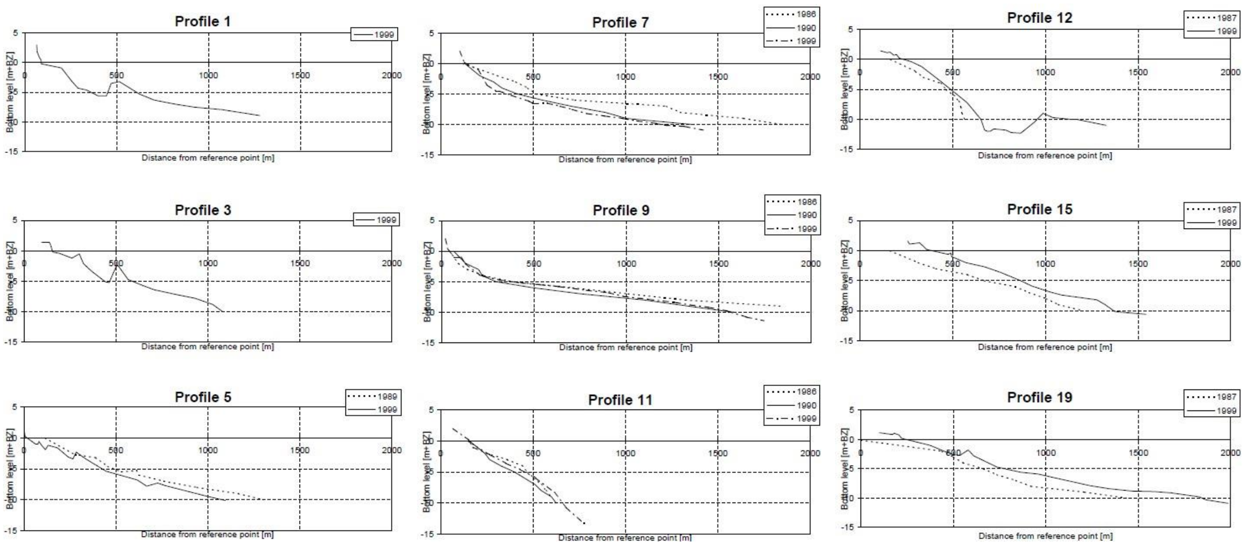


Figure 5. Measured profiles in Poti area: a) South of the City Channel, b) Didi island, c) New Rioni Delta.[9]

Just south of the South Channel (profile 5) the erosion between 1989 and 1999 was in the order of 10 m/yr. Further to the south there is a sandbar present at a water depth of approximately 5 m, extending till the mouth of the Supsa River. Along the coastline of the Didi Island the coastline is remains stable because of the revetment which was constructed in the 1960's and 1970's. It can be seen however that the underwater profile near the mouth of the South Channel (profile 7) is developing towards a steeper profile. It is expected that the rock dump will be damaged in the future because of undermining by scour. At profile 11 near the breakwater of Poti port the accumulation of sediment at the slope of the canyon can be seen. Since 1990 the vertical accretion is approximately 1 m. If more sediment accumulates along the slopes of the canyon, it is possible that the canyon is activated again in the future. This could result in damage to the port breakwater and the revetment along the Didi Island.

Profiles north of the Poti port show, that due to the shifting of the Rioni River to the north of Poti, the coastal area is accreting. Just north of the port the coastline is accreting only slowly. The presence of the port access channel may be the reason for this. Profile 12 is relatively steep because the access channel is close to the coastline. Part of the material from the Rioni river is currently transported into this access channel instead of causing accretion near the waterline. Further to the north the Nabada Delta is accreting faster. Between 1987 and 1999 the accretion rate was in the order of 15 to 20 m/yr.

Sediment characteristics. In July 1999 sediment samples were taken at several location along coastline between Poti and the Supsa River. Based on a sieve analysis, the characteristic grain size diameters D_{50} and D_{90} were computed (see Figure 6). The samples numbers are referring measured cross-shore profiles.

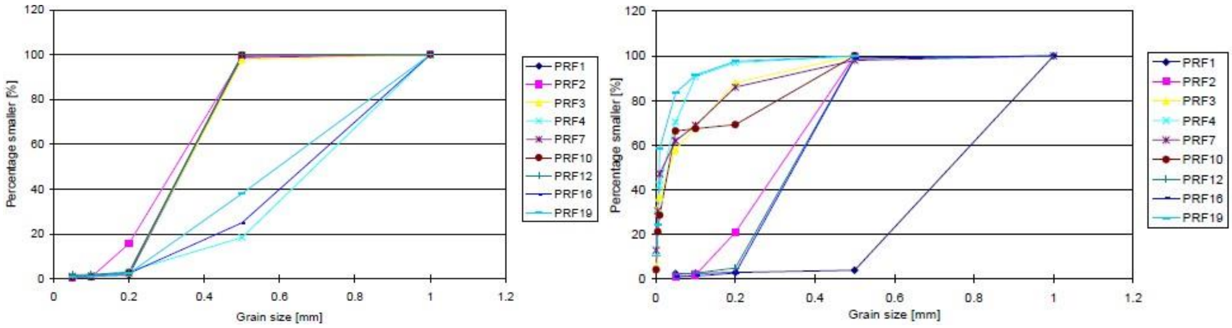


Figure 6. Sediment samples from different locations along the coastline (left: waterline, right: 5m depth).[9]

As can be seen from the results, there is a large deviation of the grain size along the coastline. This could be explained by the presence of the river mouths. When a river discharges water and suspended sediment, the flow velocity suddenly decreases at the river mouth. This causes deposition of the sediment over a distance of a few hundred meters. Large part of the fine material will be deposited in front of the river mouth. Due to wave action the fine fraction will be washed out and the coarser fraction will slowly be transported to the shore. This explains why along profile 4 fine material is found at 5 metres water depth and coarser material is found near the waterline.

In Arcadis (2000)[9] only the upper part of the coastal area was modelled, where sand with a median grain size of 350 µm is found as can be seen from Figure 6. The sediment in the lower part of the coastal area does hardly consist of beach forming sediment (defined as sediment smaller than 200 µm).

Wind and wave climates

A prediction of the offshore wind induced and local wave climates in the nearshore area is of great importance for making reliable predictions of sediment transports along the coastline. Importantly, the direction of the incoming waves in relation to the orientation of the coastline results in the direction of the longshore transport of sediment. Since the longshore transport of sediment is approximately proportional to the wave energy, the yearly average direction of the wave energy determines the yearly averaged direction of the longshore transport by waves.

For detailed analysis a reader is referred to Arcadis (2000)[9], providing only the key results below. Frist the TU-Delft model HISWA (HIndcast Shallow water WAves) was applied to transform wave climate from the open sea to the nearshore locations (marked with asterisk on the map). Bottom bathymetry configuration used and some modelling results for offshore directions 195°N, 255°N and 345°N are shown on Figure 7.

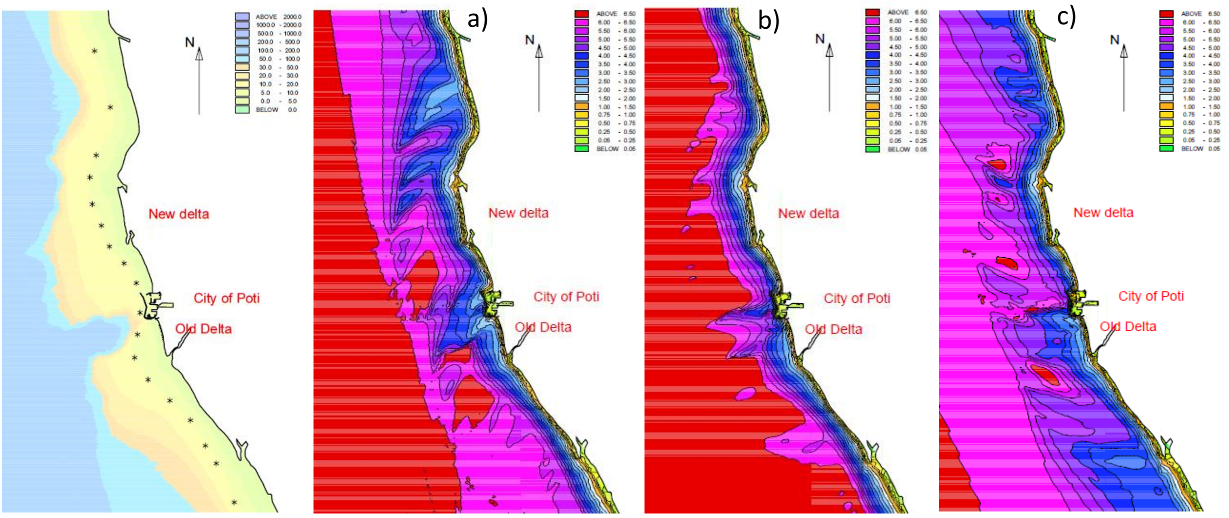
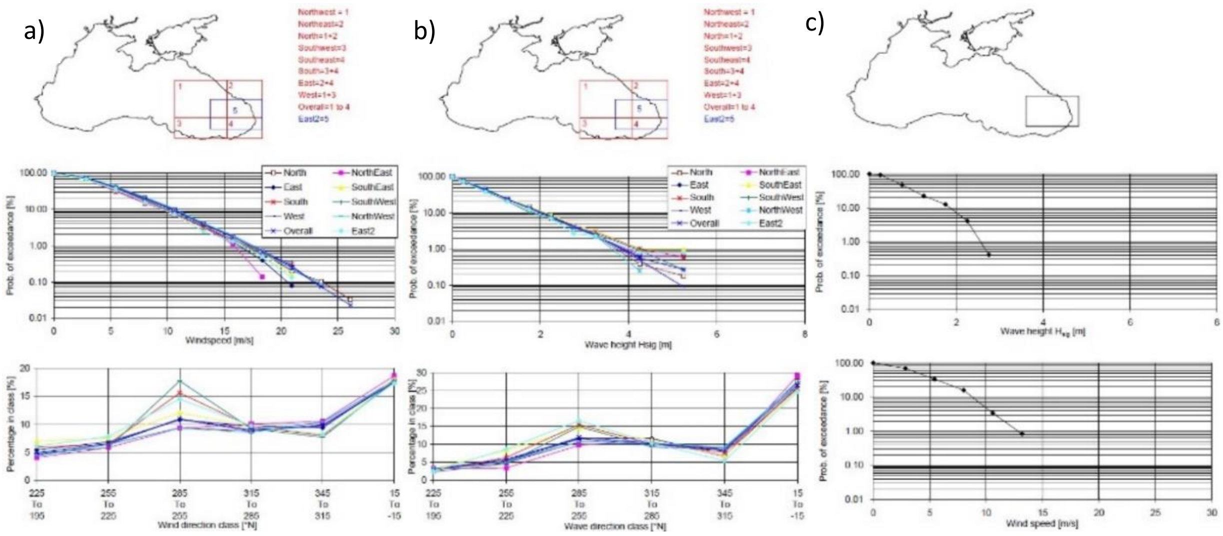


Figure 7. Depths for Poti area and result of HISWA-computations for offshore significant wave height 6.5 m and directions 195°N (a), 255°N (b) and 315°N (c) (Arcadis, 2000).[9]

The following can be concluded from wave climate nearshore modelling:

- In case of waves approaching from southern directions, strong refraction occurs in the nearshore area of Poti and the wave height decreases strongly.
- Above the submarine canyon near the port the wave height is smaller in comparison to the surrounding area. This is caused by refraction at the edge of the canyon.
- When waves approach coastline almost perpendicular, waves are still relatively high in the nearshore area. Strong refraction on the slopes of the canyon can be seen for perpendicular waves as well.
- Waves from north-western direction are strongly refracted, but still waves with a height in order of 4.5 m will reach nearshore area. Dissipation due to breaking & bottom friction reduce wave height strongly.

Wind and wave data in Arcadis (2000)[9] were derived from various sources, such as database with ship observations of waves and wind; satellite observations of the Black Sea; wind and wave data from UK hindcast model; several wave and wind measurements from Georgian sources (see Figure 8).



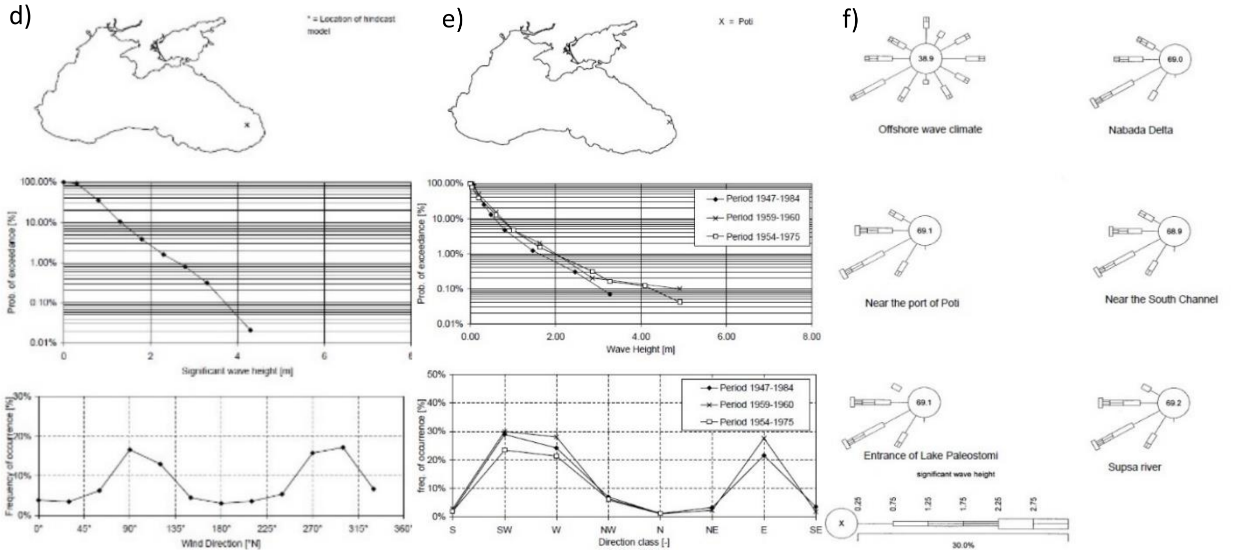


Figure 8. Wind and waves in Eastern Black Sea from: ships (a, b), satellites (c), hindcast modelling (d), Poti (e) observations and the final modelling results for wave roses near Poti (f).[9]

As can be seen from Figure 8f, the wave climate along the coastline of the Poti area is not varying much. However, some small changes can be seen. Just north of the mouth of the northern branch of the North Channel relatively more waves approach from north-western direction. This is caused by refraction of waves from the west. Just south of the mouth of the North Channel the westerly directed waves are refracted more to a south-western direction. Also, further south this refraction of waves to a direction perpendicular to the coastline can be seen. When for example looking at the locations just north and just south of the Supsa river, it can be seen that just north of the Supsa River the waves approach more from south-western direction in comparison to the location just south of the Supsa River.

Sediment transport in the coastal system

The *longshore transport* of sediment in Arcadis (2000)[9] was computed with the mathematical model UNIBEST-LT. Within this model longshore transport capacity can be computed along a cross-shore profile.

The sediment transports were computed at various locations along the coastline between Poti and the Supsa River by using computer models. Distinction is made between transports in longshore and cross-shore direction. The computed longshore transports are then used to assess the coastline changes. Cross-shore transports are determined to investigate the possible loss of sediment from the nearshore area (depth smaller than say 8 m) to deeper water.

To determine whether or not *cross-shore transport* has a significant influence on the sand balance, cross-shore transport computations in Arcadis (2000)[9] were performed with UNIBEST-TC model. In this model the development of a cross-shore profile under combined influence of waves and currents is simulated. From modelling results it can be concluded, that offshore losses of beach forming material is not expected to occur. It is therefore believed that all beach forming material, which is discharged by rivers, will be transported longshore the coastline in the upper part of the profile.

Results of modelling coastal system, described in Arcadis (2000),[9] can be presented as follows (Figure 9):

A total volume of 200 000 m^3/yr is discharged through the South Channel.

A volume of 40 000 m^3/yr is transported to the north along the Didi Island, approximately 10 000 m^3/yr is eroded. In total 50 000 m^3/yr is transported into the submarine canyon.

The remaining 160 000 m^3/yr is transported to the south. The transport capacity along the coastline south of the South Channel is 350 000 m^3/yr. This means that (350 000 – 160 000 =) 190 000 m^3/yr is eroded from the coastline.

Further to the south transport capacity decreases and 50 000 m^3/yr accumulates at the coastline. Near the Supsa River the transport capacity increases again and 50 000 m^3/yr is eroded from the coastline.

Figure 9. Overview of the coastal system at Poti area between 1983 and 1999.[9]

Results of modelling the coastline changes due to longshore transports

In Arcadis (2000)[9] hydraulics of river Rioni is also modelled and forecast of the river sediment discharges up to 2025 was given as well. These figures were implemented in the calibrated coastline model and computations were done for the period of 1999 till 2025. Model computed areas of erosion and accretion in the next 25 years, drawn on a map of Poti area, Arcadis (2000)[9], are illustrated on a Figure 10. See coastal changes also at https://www.planet.com/stories/poti-coastline-change-2017-2023-SsHwvmxIg.

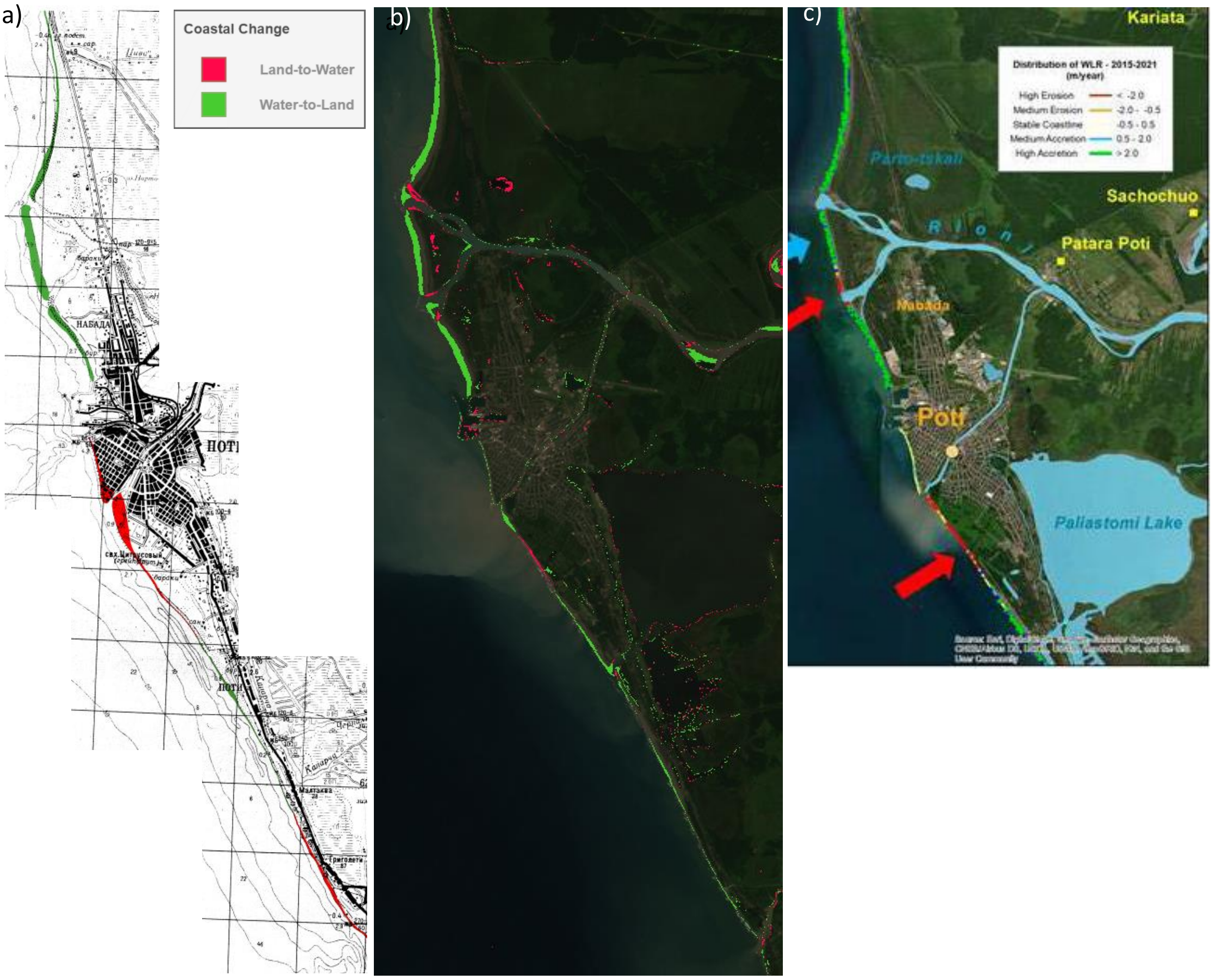


Figure 10. Coastal change a) modelling 25 years per do nothing scenario 1999-2025 (Arcadis, 2000)[9] versus factual change b) 1999-2016 (Data Cube, Landsat 7) and c) 2016-2021 (Megvinetukhutsesi et. al, 2022).[10]

Key findings of the modelling can be summarised as follows:

[10] Megvinetukhutsesi et. al, Report on Dynamics of Coastal Line Changes, PONTOS, GA, Tbilisi, 2022 https://pontos-eu.aua.am/wp-content/uploads/2023/03/GRAL_Report-on-dynamics-of-coasltine-change_Eng.pdf

- Near the South Channel erosion of approximately 300 m was expected within 25 years. A few kilometres to the south the accretion was expected to continue for the next 25 years. Near the Supsa River the coastline was expected to still eroding after 25 years in the order of 30 m.
- North of Poti port the accretion of the Nabada Delta would continue over the next 25 years with the maximum accretion in the order of 150 m, following the computer modelling. Approximately the same amount of accretion was expected to the north of the northern Rioni branch.
- Near the Poti port hardly any accretion was expected in the future. A large amount of sediment, which is transported from the north, would eventually end up in the access channel and as long the access channel to the port was maintained not much accretion therefore expected in the region just north of the port.

Actual changes of the coastline

Almost 25 years already passed since 1999 modelling by Arcadis (2000)[9] and it is time to evaluate the forecasts. It is indeed striking how well these patterns are revealed in factual remote sensing detected in the period of 1999-2016 utilising Data Cube, Landsat 7 and 2016-2021 utilising USGS Digital Shoreline Analysis System (DSAS)[11] tool (see Figure 10b and c). This indeed confirms the quality of the research and confidence in forecasts, that can form an excellent basis for operational HYMO monitoring for the future.

Coastal protection scenarios

The protection scenarios (including the scenario of doing nothing), which were defined in Arcadis (2000),[9] in close cooperation with the Georgian experts, are described below.

Following alternatives were not studied due to major concerns:

1. *New south channel through Poti via Kaparchina River.* This alternative was declined as flow velocities cannot guarantee to transport sufficient beach forming sediment and discharge planned reaching the Black Sea coast at a location where even some accretion is observed. Alternative therefore is considered not to be a feasible solution for coastal protection.

2. *Excavation of a new canal from Rioni River upstream of the sluice works to the Black Sea.* The idea was neglected for environmental and financial reasons: the canal would have to be excavated through the vulnerable and protected Kolkheti wetlands; costs for such canal and diversion would be extremely high.

3. *Increasing the flow area of the South Channel by widening and deepening.* Within the city limits widening would be almost impossible and would also worsen the channel bank erosion problems.

The defined protection scenarios considered are the following (see Figure 11):

Scenario 1: Do-nothing is defined as for 25 years nothing is done for protection of the coastline. Profile measurements show, that the erosion of the underwater profile along the revetment that continues may lead to its undermining and failure. Following options were considered:

1a do-nothing with revetment assumes revetment remains stable next 25 years.

1b do-nothing without revetment assumes revetment collapses at the beginning of the 25 years period.

[11] https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas

Because of the risk of possible canyon activation, nourishments along the Didi Island are dangerous and were excluded from consideration.

Scenario 2: SOFT coastal protection includes following options:

2a: Material from the Nabada Delta consists of artificial nourishments along the coastline south of the South Channel and the eroding coastline north of the Supsa River. The required material could be taken from the area north of Poti, from the Nabada Delta and transported to the coastline south of the Port of Poti by a dredge or a barge.

2b: Material from the Rioni River consists of artificial nourishments along the coastline south of the South Channel and the eroding coastline north of the Supsa River. The source of the sediment is the Rioni River upstream from the sluice works, transported to the coastline by the use of pipelines and pumps.

2c: Increase of the river discharge through the South Channel was already implemented in 1984-1987 reaching discharge values as high as 400 m^3/s, but this led to bank erosion in the channels flooding Poti and destabilisation of the Poti deep-water canyon and increased risk for Poti port breakwaters.

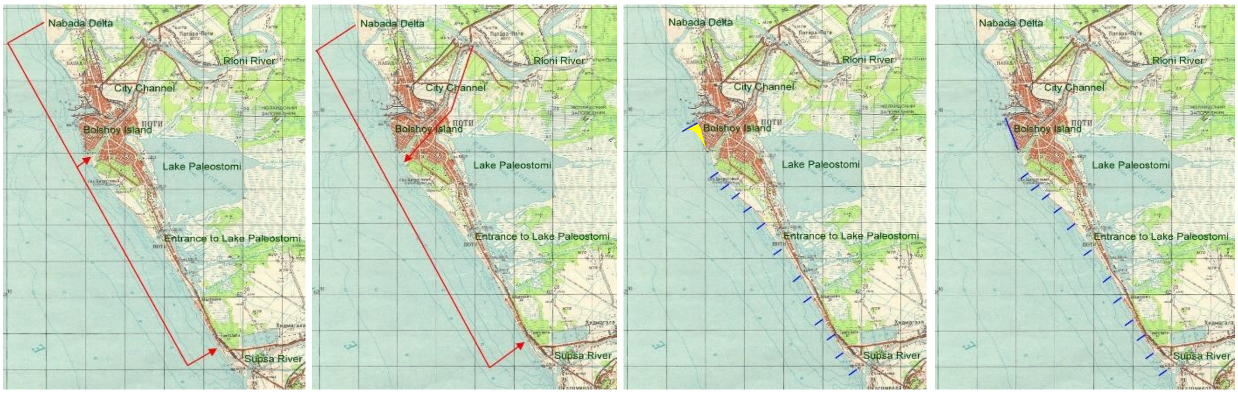


Figure 11. Schematic visualisation of scenarios (left to right): SOFT 2a) nourishments with material from Nabada; 2b) nourishments with material from Rioni River; HARD 3a) groynes from Poti port to r. Supsa (large groyne at Didi island); 3b) groynes from South Channel to r. Supsa (revetment restoration at the Didi island).[9]

Scenario 3: HARD coastal protection includes following options:

3a: small groynes and one large. With smaller groynes the coastline sections will develop an orientation which matches the discharge of sediment from the South Channel (assuming no sand is lost in offshore direction). The length and the distance between the groynes are related. To prevent sediment transport into the canyon and its activation, a large groyne is proposed northern part of Didi Island, blocking the sediment from the south and developing sandy beach updrift of the large groyne (shown in yellow).

3b: A combination of groynes and a revetment. Along the Didi island a revetment protects the coastline and has proven to be suitable for erosion control. The underwater profile beneath the revetment is however eroding and serious damage to the revetment is expected to occur. As a protection the existing revetment could be re-built. The toe of the revetment should be constructed at a larger water depth and the existing revetment has to be reinforced. For the coastline section between the South Channel and the Supsa River the same groyne system is proposed as described for scenario 3a.

Cost-benefit analysis and evaluation of scenarios

In this part the results of the cost-benefit analysis are described per Arcadis (2000).[9] In this analysis the cost of the various protection schemes are compared with the benefits of protecting the coastal land in terms of the value of the properties and assets in the coastal area that will be eroded in the next 25 years if no measures were taken (Do-nothing scenario).

Even in the case of the Do-nothing scenario, investments (estimated at 2.1m USD) and maintenance (estimated at 4.1m USD for 25 years) are required for rehabilitation of the sluice works in the Rioni river and flood protection measures along the South Channel, total costs estimated at 6.2m USD for 25 years. National prices were used in estimating Do-nothing scenario.

The Do-nothing scenario determines potential impacts if nothing is done, notably loss of land and assets thereon. It defines the base case against which all other options are measured.

The benefits of each protection option are defined in terms of avoiding the consequences of doing nothing. The Do-nothing scenario is defined in turn by the objects, including land resources and assets thereon which will be partly or completely destroyed by the actions of the sea over the next 25 years if nothing is done within this period to avoid this from happening. An inventory of these benefits based on a description of current values were estimated in total value at 49m USD.

The Table 2 provides a summary of the cost-benefit analysis expressed in economic terms for each of the protection scenarios for Poti area. Costs and benefits are expressed in present values using a discount rate of 5%. An IRR has not been provided due to limited reliability of the calculations. A benefit-cost ratio has instead been calculated with b/c ratio set at 1.35.

Table 2. Benefit-cost analysis of alternative options

Protection Scenarios for Poti	**Total costs 10^6 USD**	**NPV of costs 10^6 USD**	**NPV of benefits 10^6 USD**	**NPV 5% discount 10^6 USD**
2a) Nourishment from Nabada Delta	76.7	48.3	34.1	-14.2
2b) Nourishment by pipelines from the Rioni River	107.1	63.7	34.1	-29.6
2c) Increased discharge through the South Channel	38.9	25.2	34.1	+ 8.9
3a) Groyne system	54.4	38.6	34.1	- 4.5
3b) Groyne system and revetment at Didi Island	58.3	40.8	34.1	-6.7

Only Scenario 2c (Increased discharge through the South Channel) with NPV of 8.9m USD at b/c ratio 1.35 is found economically viable. All other options have been found to be substantially sub-economic.

The protection scenarios were also evaluated per following criteria (see Table 3):

(i) The *flexibility* of the scenario gives an indication of how easily the protection scenario can be adjusted;

(ii) The *reliability* of the scenario indicates the actual effectiveness of the scenario;

(iii) The *risk* means damage that could be caused by structures along the coastline.

Table 3. Cost-benefit analysis of alternative options

Scenarios	**Flexibility**	**Reliability**	**Risks**	**SCORE**
2a) Nourishment from Nabada Delta	+2	+1	-1	+2
2b) Nourishment by pipelines from the Rioni River	+2	+1	-1	+2
2c) Increased discharge through the South Channel	0	-1	-2	-3
3a) Groyne system	-1	0	-1	-2
3b) Groyne system and revetment at Didi Island	-1	0	0	-1

(+2) very positive (+1) positive (0) neutral (-1) negative (-2) very negative

The economically most favourable solution has lowest risk rating and reliability, neutral flexibility. In Arcadis (2000)[9] therefore the most-promising solution is considered a combination of scenarios 2a and

3b: nourishment from Nabada Delta 250 000 m^3/yr just south of the South Channel and 50 000 m^3/yr near the Supsa river, and reinforcement of revetment at Didi Island. But nourishment from Nabada Delta will put Poti in competition with coastal oil refinery under construction on the right side of Nabada Delta.

Bed disturbance

In addition to coastal protection activities and related hydrological modification, bed disturbance can be caused by dredging, dumping, fishing and other activities: e.g. Poti port regularly dredging its access channel, while per resolution of the Government of Georgia № 423 December 31, 2013, On Approval of Technical Regulation for Fishing and Preservation of Fish Stock[12] bottom trawling is not allowed outside the zones defined in Article 7, specifically in Clause 5, which defines bottom trawling Zones I, II, III by indicating geographic coordinates of edges of the rectangular shaped areas (Figure 12).

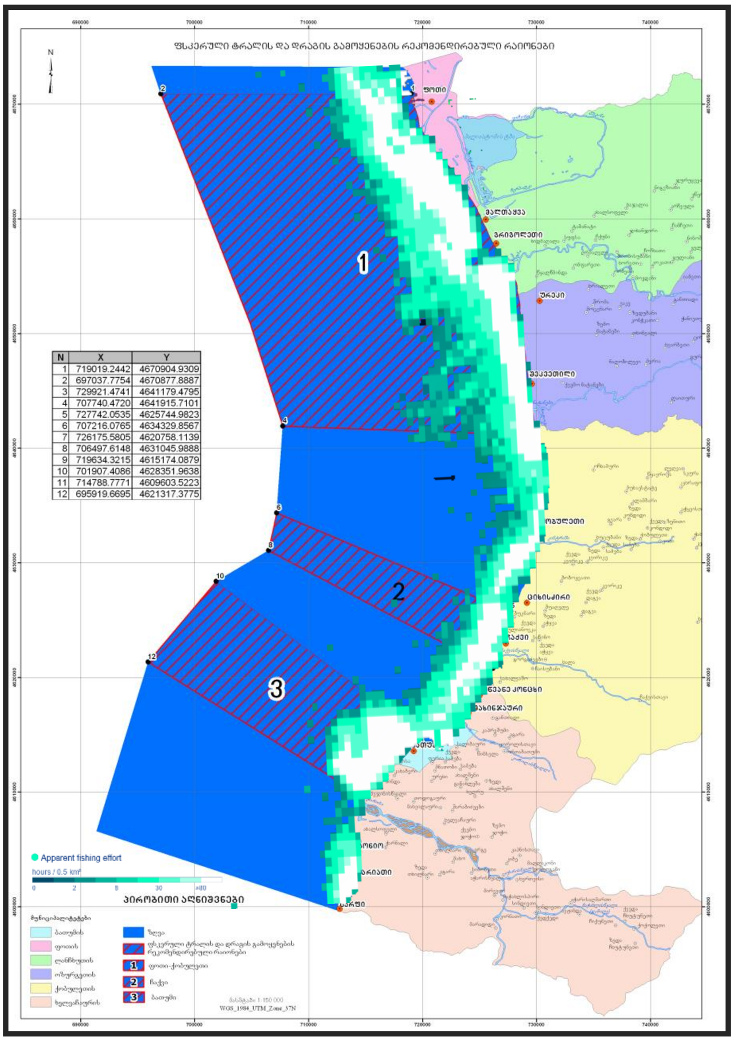


Figure 12. Bottom trawling zones I, II, III zones (source NEA) overlaid with last 10 years of the fishing activity in Georgia (source GFW[13]).

[12] https://www.matsne.gov.ge/document/view/2187155?publication=0

[13] https://globalfishingwatch.org/map/fishing-activity/from_jan_1_2014_to_jan_1_2025_near_georgia-user-public

Climate change induced Sea Level Rise

Sea Level Rise (SLR) measurements in Georgia are generally in line with well-documented global trends of approximately 20 cm SLR for last 120 years, characterized globally with accelerated rates, increasing from 2.6 mm/yr in previous to 3.3 mm/yr in this decade[14] and as recently as this year global average SLR jumped by about 7.6 mm/yr from 2022 to 2023.[15] Uncertainty is not about whether climate change would cause high sea level rise, rather plausibility of multi-decadal rather than multi-century timescale for multi-meter SLR timescales,[16] although it is very realistic that sea level would rise above 1 m this century, which would indeed be consequential for Poti (see Figure 13).

The region around Poti is reported to subside with a rate of about 5.5 to 6 mm/year. The combined effect of Relative SLR for the Poti area in Arcadis (2000)[9] was estimated at 8-9 mm/year and this value has been adopted as most likely scenario, but after 25 years maximum scenario of 13.5 mm/yr seems more likely.

Figure 13. Inundation of Poti in case of 1 m global SLR (inset: flood resilient house in Poti).[17]

[14] Hansen et al. 2016: Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modeling, and modern observations that 2 0C global warming could be dangerous, Atmos. Chem. Phys., 16, 3761–3812, 2016. https://acp.copernicus.org/articles/16/3761/2016/acp-16-3761-2016.pdf

[15] https://www.nasa.gov/earth/oceans/nasa-analysis-sees-spike-in-2023-global-sea-level-due-to-el-nino

[16] Statement with *medium confidence* that 'Marine ice sheet instability in Antarctica…' '…could result in multi-metre rise in sea level…' found its place in most recent IPCC Summary for Policymakers of 2018 (see B2.2. S and Figure SPM.2 in http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf).

[17] https://coastal.climatecentral.org/mapview/12/41.7832/42.1237/c763c7aa5e93a998d270ef07928b7383e8d0316a1b66a719449df6e7fd7d810b

Concluding this chapter, one can summarise, that the coastline of the Poti area has undergone significant anthropogenic and natural changes. Man-made alterations, including the redirection of the Rioni river mouth in 1939 and subsequent attempts to mitigate erosion through engineering interventions, have reshaped the coastal hydromorphology. These efforts, such as the construction of the North Channel and various coastal protection measures, have influenced sediment transport dynamics and shoreline evolution. However, the effectiveness of these interventions has varied, with some leading to unintended serious consequences, such as canyon activation and erosion exacerbation.

Furthermore, natural processes, such as sediment transport and wave climate, have interacted with anthropogenic modifications, influencing coastal erosion and accretion patterns. Sediment characteristics, wind and wave climates, and sediment transport dynamics have all played crucial roles in shaping the hydromorphological characteristics of the Poti area, both along the coastline and in the hinterland.

Although methodologically not directly part of the hydromorphological assessment, looking ahead, the impacts of climate change, particularly sea level rise, pose significant challenges to the Poti area. The combination of global sea level rise trends and local subsidence rates necessitates proactive adaptation measures to mitigate the potential risks to coastal communities and infrastructure.

In summary, a comprehensive understanding of both anthropogenic and natural influences on HYMO characteristics is essential for effective coastal management and adaptation strategies in the Poti pilot area. Integrating this knowledge into decision-making processes will be crucial for ensuring the long-term sustainability and resilience of this coastal zone.

3. Reconnaissance of Poti area HYMO Sites

Site visit for physical reconnaissance of the HYMO sections was performed on 3rd of February 2024.

The locations visited and documented with photos are displayed on Figure 14 together with HYMO sites and sections (Figure 14).

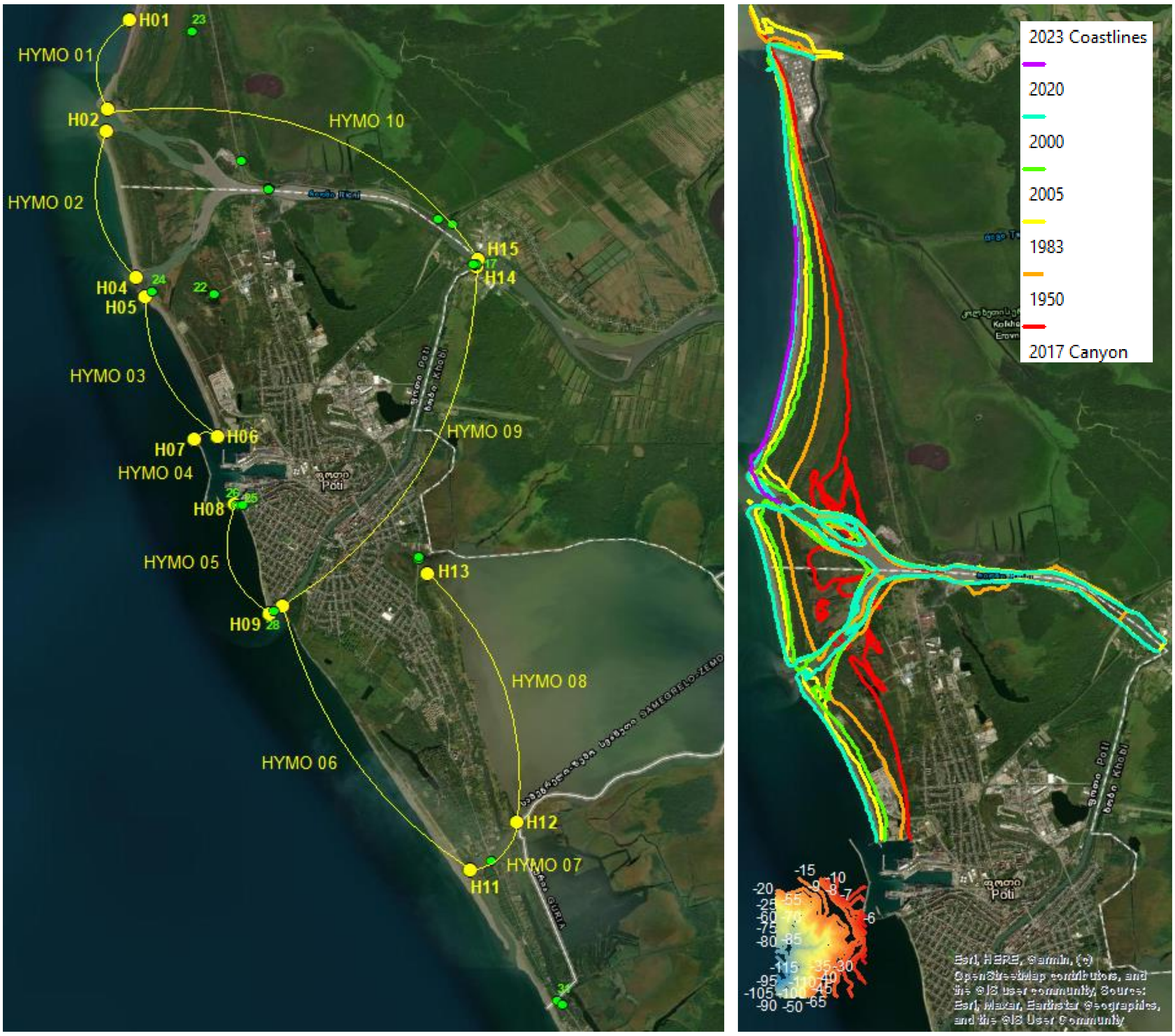


Figure 14. Left: HYMO points & sections (yellow), site photos (green). Right: coastline changes, canyon depths.

Data log form

For documentation of the site visits the following data log was developed which can also be applied for HYMO assessment field reconnaissance and proposed for use for other sections of Georgian coast (see Table 4):

Table 4. HYMO field reconnaissance data log form

NEA HydroMorphological Assessment Field Reconnaissance Form (Source: EU4Environment)					
Water body:			**Geographic coordinates:**	Lat:	
Section (from-to):				Lon:	
Observing person(s):				**Date:**	YYYY.MM.DD
#	**HYMO Metrics**		**Field reconnaissance observations for respective metrics (please check)**		
1a	Shoreline alteration	☐			
2a	Water body barriers	☐			
1a	Shoreline alteration	☐			
2a	Water body barriers	☐			
3a	Bed disturbance	☐			
3b	Change in habitats	☐			
4a	Marshlands, seagrass beds change	☐			
5a	Tidal regime, floods, sea level change	☐			
6a	Changes in wave regime	☐			
7a	Change in river flow	☐			
7b	Change in residence time	☐			
8a	Dominant particle size changes	☐			
8b	Change in turbidity	☐			
9a	Change to stratification	☐			
9b	Change in salinity	☐			
Photo documentation, geolocation map, etc.					

Photo-documentation

Site visit photos are reproduced below (Figure 15-Figure 31) with brief explanations in captions.

Figure 15. Bridge over the Lake Paliastomi connection to the Black Sea (litter intercept visible).

Figure 16. View from highway bridge towards r. Kaparchina (left) and l. Paliastomi (KNP).

Figure 17. R. Rioni upstream of North Channel and South Channel sluices.

Figure 18. South Channel view (HYMO 09) from the sluice works (left) and crossing bridge.

Figure 19. North Channel immediately downstream the sluice works (HYMO 10).

Figure 20. Railway and new highway bridges (left); gas pipeline aerial crossing (right) over Rioni.

Figure 21. Old bridge with WWTP pipe: up & downstream views of North Channel (see dredger).

Figure 22. Potential rise cultivation site in Poti FIZ (culvert connects wetlands on both sides).

Figure 23. Dredging works and WWTP construction (left); construction of Oil Refinery next to KNP.

Figure 24. Nabada Delta southern branch: northward (top) & southward (bottom) panoramas, FIZ.

Figure 25. Didi island south of Poti port (fish berth): rubble disposal and remnants of old groynes.

Figure 26. Pumping station & sewage discharge north of Didi Island & south of fish berth.

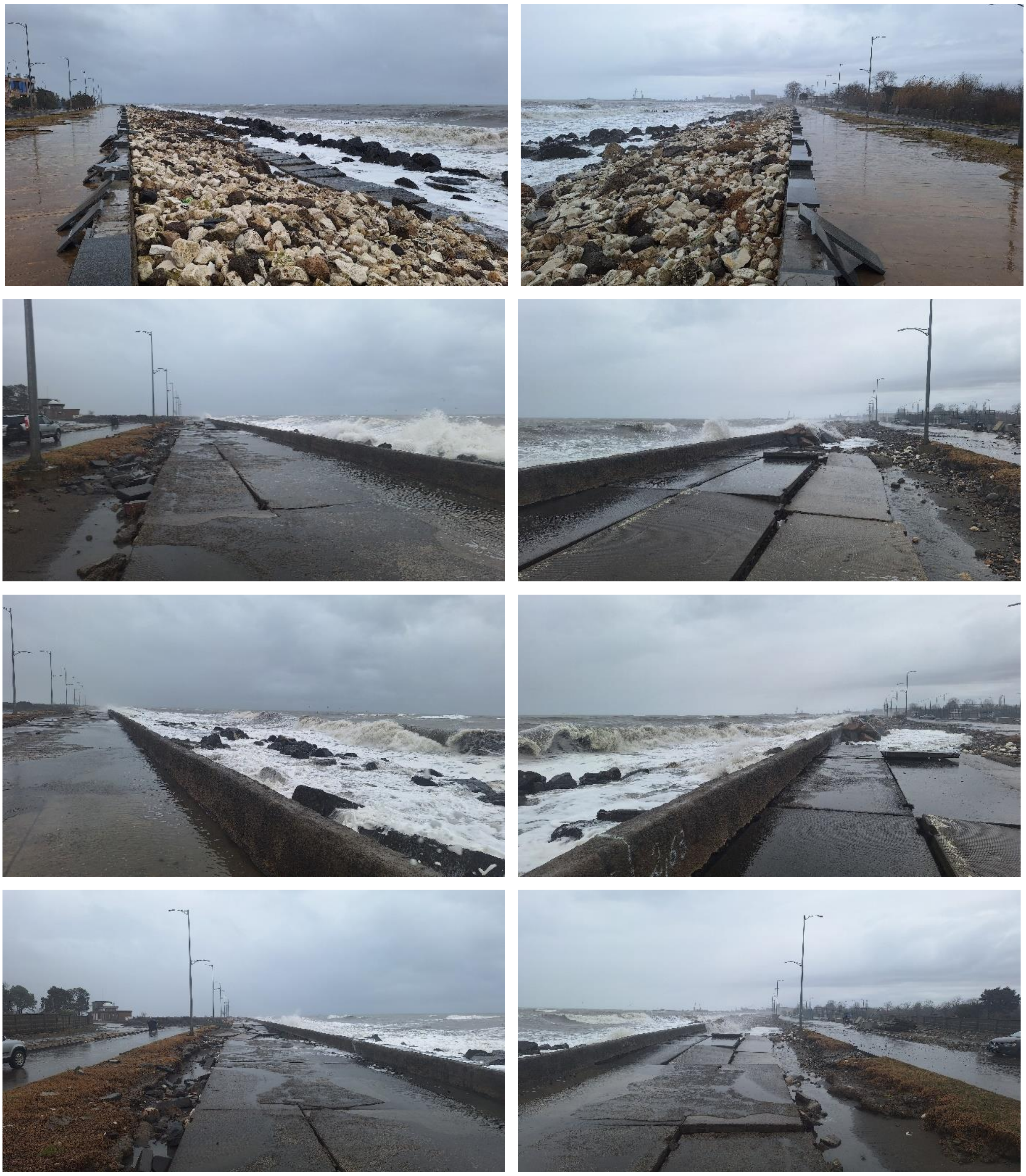


Figure 27. Visual condition of the Didi Island revetment, moving from the north to the south.

Figure 28. Southern Channel delta: south (lighthouse, hydrography service) and sea panoramas.

Figure 29. Undisturbed coastline south of Poti.

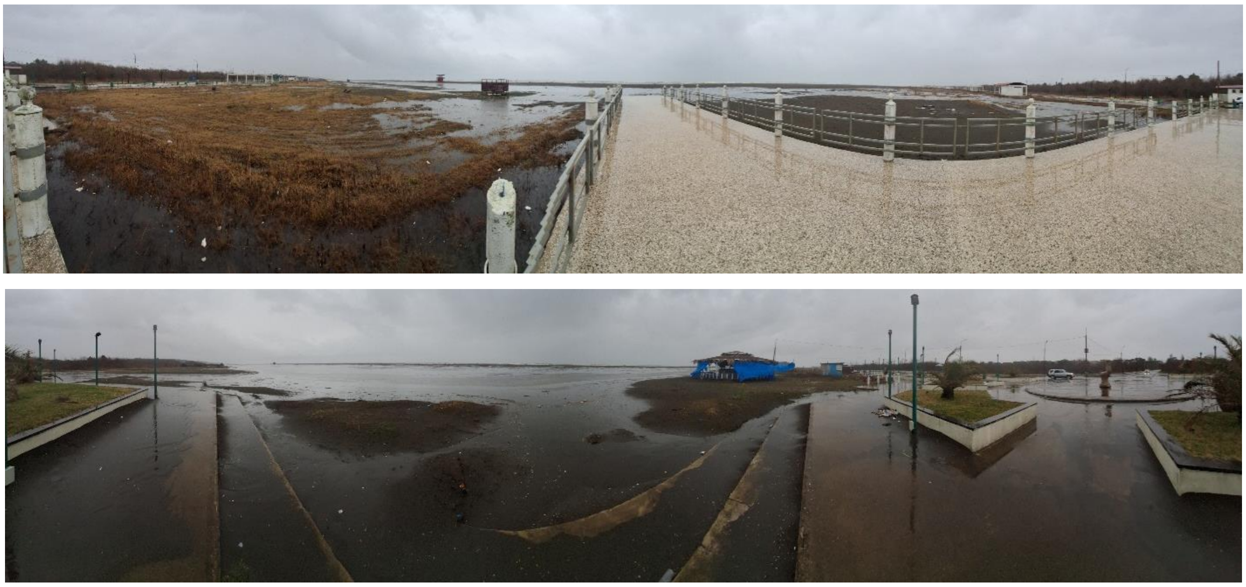


Figure 30. Inadequately designed and placed recreation infrastructure further south of Poti.

Figure 31. Aqueduct over old (now defunct) connection of Kaparchina River to the Black Sea.

4. Classification of HYMO quality elements for CTW bodies

Table 5 reports HYMO classification of CTW bodies in Poti pilot area by summarising the HYMO Quality Index based on qualitative assessment of CTWs per each metrics as provided in the HYMO Methodology.

Table 5. Summary matrix for HYMO Quality Index of Poti pilot area

#	HYMO METRICS and Quality Element Scores / CTW Bodies and HYMO Sections	**TW11_Ri** Rioni estuary (02, 10)	**TW12_Pl** Paliastomi lake (06, 07, 08, 09)	**CW111_RiC** Rioni - near coast (01, 02, 03, 10)	**CW211_PoHa** Poti harbour (04, 10)	**CW212_KbRi** Kobuleti to Rioni estuary (02, 03, 04, 05, 06, 07, 09)	**CW212_RiKo** Rioni estuary Kodori cape (01, 02, 10)
	Legend	**#** Score	**0** High	**1** Good	**2** Moderate	**3** Poor	**4** Bad
01	Metric 1a. Shoreline alteration	1	1	1	2	2	1
02	Metric 2a. Presence or absence of barriers within/between water bodies	1	1	1	2	1	0
03	Metric 3a. Bed disturbance	1	1	1	4	2	0
04	Metric 3b. Change in habitat	1	1	1	2	1	1
05	Metric 4a. Change in the spatial extent of Marshes and/or Seagrass beds	2	0	2	2	1	3
06	Metric 5a. Change in tidal regime, floods & sea level	3	1	3	2	3	2
07	Metric 6a. Changes in wave regime	1	0	1	1	2	0
08	Metric 7a. Change in river flow	2	1	2	2	3	1
09	Metric 7b. Change in residence time	1	2	1	3	2	1
10	Metric 8a. Change in dominant fraction particle size	2	1	2	2	1	2
11	Metric 8b. Change in turbidity	3	1	3	1	2	2
12	Metric 9a. Change to stratification	1	1	1	1	1	1
13	Metric 9b. Change in salinity	1	2	1	1	1	1
14	**HYMO Alteration Index HAI=S_{total}/S_{max}**	0.38	0.25	0.38	0.48	0.42	0.29
15	**HYMO Quality Index HQI=1-HAI, couloir range: 0 – 1**	**0.62** Moderate	**0.75** Moderate	**0.62** Moderate	**0.52** Poor	**0.58** Poor	**0.71** Moderate

It should be noticed, that data is unavailable to quantitatively derive all metrics listed in Table 5; hence, expert judgment was employed to estimate certain metrics, notably: 3b (change in *marine* habitats portion), 4a (lack of information on *seagrass beds*; metrics can be derived for *marshlands*), 7b (*residence time* data unavailable), 8b (absence of data and information on *turbidity*, only accessible through data cube analysis for marine areas), as well as 9a and 9b (measured data on *stratification* and *salinity* not provided). Accordingly, prioritising the respective data sources for future measurement efforts is crucial. It is also recommended to develop GIS routines for data entry and visualization for all metrics, drawing from European experience, such as the CTW Morphological Impact Assessment System (MImAS) tool (although the authors of this report were unable to identify a corresponding digital tool in open domain).

Results with respect to HQIs are visualised for CTW bodies for Poti pilot area on Figure 32.

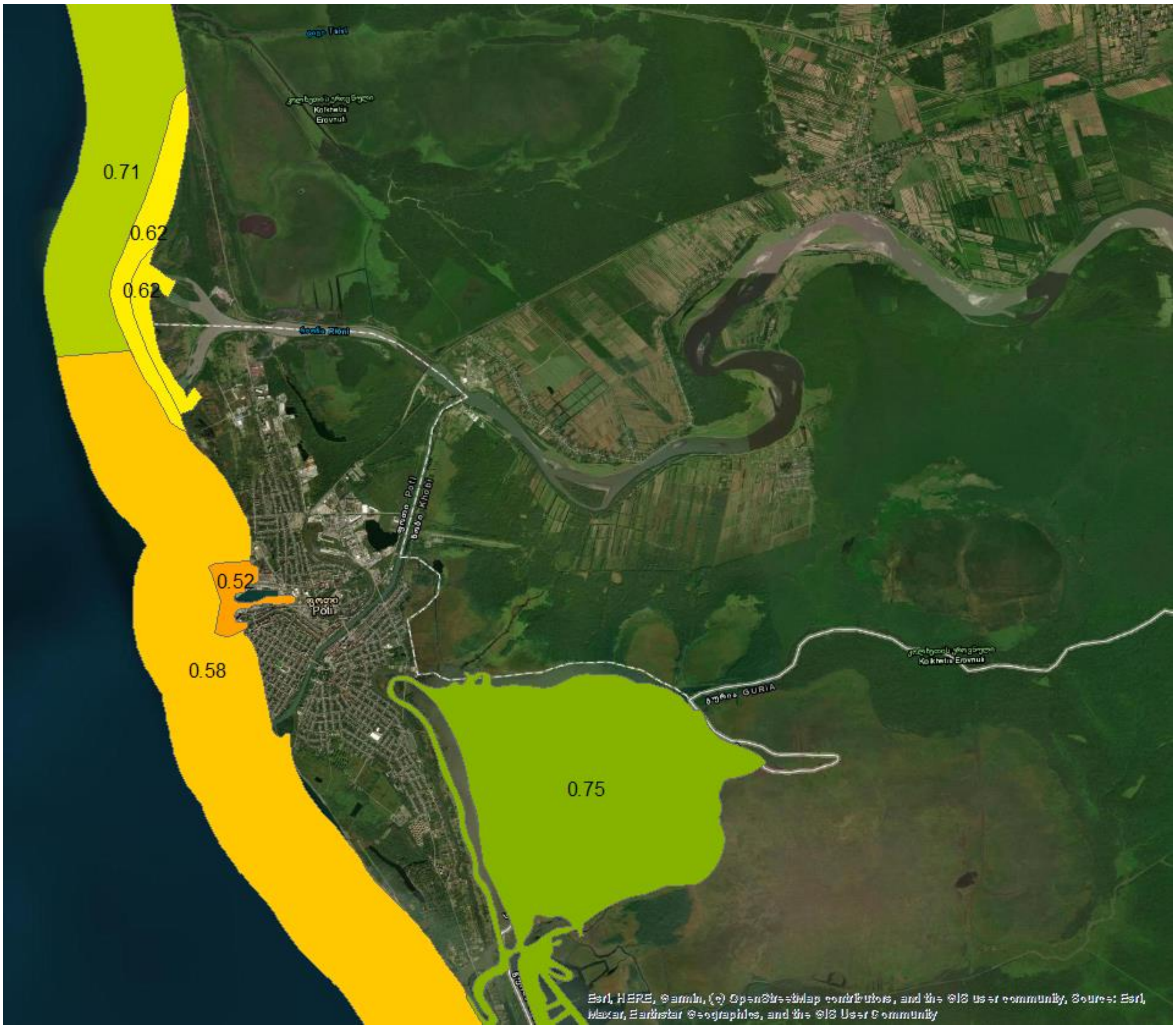


Figure 32. Visualisation of HYMO Quality Index for CTW bodies of Poti pilot area.

5. Conclusions

The conclusions drawn from the analysis presented in the document can be summarized as follows:

1. Feasibility of Qualitative Estimation: Despite limitations in quantitative data availability, it was found feasible to estimate the hydromorphological Quality Index (HQI) qualitatively using the proposed methodology for assessing HYMO status in Georgia's Black Sea Coastal and Transitional Water bodies (CTWs).
2. HYMO Quality Index (HQI) integral scores were *moderate* for Rioni estuary (estimated at 0.62), Paliastomi lake (highest score at 0.75), Rioni - near coast (0.62) and the coastal section north of Rioni estuary (0.71), while scores were *poor* for sections south of Rioni estuary (0.58) and Poti harbour (0.52), which scored lowest.
3. Incorporation of CTW HQI Mapping: Pilot testing revealed the need for adding CTW HQI mapping requirements to the next iteration of HYMO Methodology, in case found feasible.
4. Importance of Field-Based Data and GIS Observations: The analysis emphasized the importance of collecting field-based data from Water Framework Directive (WFD) monitoring and GIS observations. These data sources are essential for populating metrics required to quantify hydromorphological features accurately. HYMO field reconnaissance data log form was provided.
5. Initiation of CTW HYMO Monitoring Program: A recommendation was made for the National Environmental Agency (NEA) to initiate a monitoring program focused on measuring CTW HYMO quality elements. This program will enable the derivation of metrics necessary for calculating and mapping CTW HQI accurately.
6. Suggestions for Delineation: It is advised to consider delineating the Northern and Southern Channels of the Rioni River, respectively, as Artificial and Heavily Modified Water Bodies (latter can originate only from natural water bodies, which have been heavily changed, as is the case for Southern Channel, while Northern channel was indeed artificially created). These designations would improve assessments and management strategies for these water bodies.
7. It is considered appropriate to extend the coastal cell of the Poti area beyond the bounds of the Poti pilot area both to the South until the river Supsa and to the North until the river Khobistskali.
8. Future Updates and Revisions may also include revisions to the delineation of Georgian Black Sea CTWs, incorporating HYMO coastal cells for more comprehensive assessments. These updates are essential for enhancing the accuracy and reliability of hydromorphological monitoring and management practices in the Poti area and beyond.
9. Adaptation Plan for Poti Area: Climate change and sea-level rise would undoubtedly have severe consequences for the Poti area. Therefore, it is strongly recommended to develop an adaptation plan to address these challenges and ensure sustainability. This recommendation is not directly tied to HYMO assessment, but issue is very important for coastal and river basin management planning.

Overall, the conclusions highlight the importance of data-driven assessments, the need for ongoing improvements in hydromorphological monitoring methodologies, and the significance of incorporating field-based data for comprehensive evaluations and planning efforts. An adaptation plan for climate change is indeed essential for the sustainability of Poti and its surrounding areas.

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