

# IMPACTS OF GLOBAL CLIMATE CHANGE, SEA LEVEL RISE AND ECONOMIC-CONSTRUCTION ACTIVITY TO THE SUSTAINABLE DEVELOPMENT OF THE QUANG NINH COASTAL AREA

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**Abstract:** Quang Ninh is a great potential province to economic development, especially in the field of mining and tourism. Climate change, sea level rise and other economic-construction activities result in an increase of geological processes and phenomena, causing floods, salt infiltration that directly affect to the socio-economic development of the area. Based on analyses and assessments, the author presents basic and long term solutions to diminish the unfavorable impacts of the climate change, sea level rise and other economic activities for the sustainable development of Quang Ninh area.

**Keywords:** climate change; sea level rise; sustainable development.

## 1. Some natural characteristics and scenarios of climate change and sea level rise in Quang Ninh province

Quang Ninh is located in the northern economic development triangle of Hanoi, Hai Phong and Quang Ninh, with great potential for developing mining and tourism. Quang Ninh is characterized by hilly terrain and narrow coastal delta stretching from Mong Cai to Quang Yen. The Quang Ninh hills are in the form of rocks from Paleozoic to Cenozoic and Quaternary, mainly forming conglomerates, sandy clay, claystone, limestone formations and some origin rocks. magma of the Tan Minh, Xuan Son, Cat Ba, Bac Son, Binh Lieu, Hon Gai and Ha Coi Formations [3].

Climate change today and in the future depends mainly on the level of greenhouse gas emissions, ie the dependence on the socio-economic

development of countries around the world. Thus, climate change scenarios are based on global socio-economic development scenarios. In the special report on the Greenhouse Gas Emission Scenario (AR5) of 2000, the Intergovernmental Panel on Climate Change (IPCC) developed climate change scenarios based on a new scenario approach of greenhouse gas emissions, paid attention on greenhouse concentration more than emission, and four scenarios are RCP 2.6, RCP 4.5 (B1), RCP 6.0 (B2) and RCP 8.5 (A1FI)[1].

Based on the climate change scenarios of the Ministry of Natural Resources and Environment for the Northern Delta, the specific scenarios for Quang Ninh are as follows [1]:

### *On temperature*

Change in average annual temperature (<sup>0</sup>C) over 1986-2005.

Tab. 1a. Change in average annual temperature (<sup>0</sup>C) over 1986-2005

Scenario RCP 4.5(B1)			Scenario RCP 8.5(A1)		
2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
0.7 (0.4 ÷1.1)	1.6 (1.1 ÷2.3)	2.1 (1.5 ÷3.0)	0,9 (0.6 ÷1.4)	2.0 (1.5 ÷3.0)	3.6 (2.9 ÷4.8)

## Rainfall

Tab. 1b. Change in average annual rainfall (%) over the period 1986-2005

Scenario RCP 4.5(B1)			Scenario RCP 8.5(A1)		
2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
20.4	19.1	29.8	14.8 (6.4÷23.4)	24.0	36.8
(6.5÷33.4)	(11.7÷26.9)	(19.8÷40.9)		(14.7÷33.0)	(25.9÷46.5)

## Sea level rise scenarios

Tab. 1c. Sea level rise in Mong Cai-Hon Dau under the scenario RCP 4.5 (B1), cm

Timeline of the 21st century							
2030	2040	2050	2060	2070	2080	2090	2100
13 (8÷18)	17(10÷24)	22(13÷31)	27(17÷39)	33(20÷47)	39(24÷56)	46(28÷65)	53(32÷75)

Tab. 1d. Sea level rise in Mong Cai-Hon Dau under scenario RCP 8.5 (A1), cm

Timeline of the 21st century							
2030	2040	2050	2060	2070	2080	2090	2100
13(9÷18)	18(13÷26)	25(17÷35)	32(22÷45)	41(28÷57)	50(34÷70)	60(41÷85)	72(49÷101)

(Note: figures in parentheses are the smallest to largest variation)

## 2. Assessment on the impact of climate change, sea level rise and economic activity in Quang Ninh.

The impact of climate change and sea level rise in Quang Ninh has increased the activities of dynamics geological processes and events in the study area and is mainly expressed in intensification of rock and soil weathering, karst, slides and mudflats, increasing sedimentation of river mouths, change of coastlines, floods, semi-floods, saline water intrusion and underground water ..., detrimental to economic activities as well as human life, affecting the sustainable development of the area.

### 2.1. The processes of weathering rocks and karst.

For soil and rock weathering and karst processes and phenomena, the change of climatic factors is critical to their ability to grow, and developing intension. Temperatures and water are the major contributors to soil and rock weathering as well as promoting the carbonate dissolution that causes karst. High temperatures and sudden changes cause strong physical weathering, accelerating the intensity of chemical weathering. Water is not only the cause of weathering but also the environment for chemical reactions such as

solubility, hydration, oxidation, carbonation, ... [6]. Therefore, in the condition of abundant rain water that make moisten soil, increased water exchange capacity, chemical weathering will develop dramatically. This has been proven by reality. The areas with tropical climate, hot, humid, rainy as in the North Sea coast, the weathering is very strong, weathering products are the most absolutely, the thickness of weathering crust is big, especially strong and complete weathering zone (to tens of meters thick). For karstization, rainwater is one of the determinants of karst growth, as it governs the ability of water exchange in response to the dissolution of the rock.

The weathering process changes rocks in terms of composition, texture, structure, state, physic-mechanical properties, etc., in a manner unfavorable to construction activities such as reduction of density, void ratio, water permeability increases, durability, stability decreases, compression level increases. Weathering is not only adversely affect the geological environment but also the premise, enabling other geologic dynamics phenomena to develop, such as accelerating the formation of slides, rock fall, gullies, erosion on slopes, sloping roofs, supply of solid materials for muddy streams.

### 2.2. Rock fall

The literature has shown that, in the area of Cam Pha and Ha Long, geological hazards due to landslide occur quite strong and regular in the rainy season on the slopes, exposed mines and the slope of the disposal site as well. The sliding blocks at Bai Chay bridge end are at risk of causing unsafety to the constructions and have been repeatedly repaired and costly.

At the end of July, early August, 2015 in Cam Pha, Ha Long, there was a very heavy rain, causing

geological hazards and lots of damages to Quang Ninh. According to meteorologists, the abnormalities of the climate during this precipitation are reflected in the formation of low-pressure trough with overlapped low-centered, and nearly no movement, with total rainfall up to 1,500mm (in Cua Ong, from July 26 to August 3). The consequence of this abnormal climate is that many of the slopes and slopes of mines, slopes at coal mining sites, slopes in traffic roads are at risk of instability and slides



Fig. 1. Slope in residential area in Ha Long

### 2.3. Mud-rock flood

It is said that the reason of the mud-rock flood occurrence in the area of Quang Ninh, is not only due to rain fall, landform, flows but also the materials from slide blocks mostly, specially slides in dumping sites of mining. Loose materials formed from piping phenomenon inside the

dumping site and other slides with surface flows created from heavy and gathering rain due to climate change as well have made mud-rock flood, destroyed constructions, blinded houses, streets, seriously affected to coal mining and other economy and works activities.



Fig. 2. House accreted by mud-rock flood in Cam Pha

#### 2.4. Erosion, sedimentation, flooding and saline intrusion

According to the research program CTB-2012-02 [2], over the past 85 years, the erosion-deposition phenomenon in the Northern coastal areas has been complicated over time, both in size and intensity, especially in the delta coastal areas. The results of the current situation and the forecast of the impacts of climate change and sea level rise on erosion and sedimentation in coastal areas of Northern Vietnam according to the high emission scenario A1 show that, compared with the period

from 1930 until now, the erosion and sedimentation activity up to 2050 has been on the upward trend, but the increase amount of erosion is greater than the increase amount of sedimentation (depending on the characteristics of coastal structure and marine dynamics) in each parts of the region. In the Quang Ninh area, erosion and sedimentation occur more limited than in other coastal areas due to the impact of topographic and geomorphic factors as well as geology structure of the coastal zone.

Tab. 2. Development of erosion, sedimentation in Quang Ninh coastal areas [2]

Region	From 1930 to present				Forecast from present to 2050			
	Area of erosion (ha)	Speed (ha/year)	Sedimentation area (ha)	Speed (ha/year)	Area of erosion (ha)	Speed (ha/year)	Sedimentation area (ha)	Speed (ha/year)
Hai Ninh	181.63	2.14	144.04	1.69	200.30	5.72	119.35	3.41
Cam Pha	152.26	1.79	91.04	1.07	168.29	4.81	75.91	2.17
Ha Long	35.12	0.41	53.90	0.63	40.61	1.16	45.47	1.30

The phenomenon of erosion occurs in the coastal zone, which directly affects the estuarine sedimentation process, changing the coastline. Thus, the effects of climate change, sea level rise and the intensification of erosion and sedimentation will also increase these processes.

In the study areas of Quang Ninh, the effects of climate change, sea level rise promoted the atypical sedimentation of the river mouth and did not significantly affect the operation of coastal structures due to the system; due to tide with branch-shaped, basically retains the role of deep erosion as the tidal current of the solar tide with large amplitude.

In Quang Ninh, the coastline changed quite strongly, especially in the area of Ha Long and Cam Pha. The survey results show that from 1990 up to now, the coast of Quang Ninh has a tendency of accretion, very few eroded points and most erosion rates are very low. The tendency to expand the coastline towards the sea is mainly due to leveling activities for new residential areas, shrimp ponds, waste dumping, etc., and partly because of

the flow of minerals from waste dumps. Exploitation of coal in estuaries and coastal areas.

Thus, the main cause of significant change in shoreline in Quang Ninh is due to human activities, but the impact of climate change is not clear.

Rising sea levels will cause flooding of low-lying terrain in the studied areas. The mapping result forecasting flooding due to sea level rise in response to climate change scenarios in CTB-2012-02-04 has shown the risk of flooding due to sea level rise in the coastal area of Quang Ninh (table 3).

Quang Ninh Province is unflooded much because its mountainous terrain. Van Don is the most flooded area, the flooded area is forecasted from 63.18 to 86.36%. Ha Long, Cam Pha flooded the least, flooded area from 3.83 to 8.02%. In the coastal economic development areas of Quang Ninh and Mong Cai, the flooded areas are quite heavy, the flooded area can reach up to 30% when the sea level rises 0.85m, concentrated in the accretion, in the southern part of the area, there is a low-lying land bordered by the sea. In the flood affected area, the main area is when sea level rises

0.5m, in case of sea level rises 0.7m or 0.85m, the flood areas are more narrow strips (from 100-300m wide) developed to the boundaries of flooded area corresponding to the case of sea level rise of 0.5m.

For Ha Long area, the impact of sea level rise is not much. Areas of flood risk are mostly mudflats, tidal flat located deeply inside the bay. In addition,

the risk of flooding also occurs on some coastal sections, stretching in narrow strips, broken in Hong Ha, Hong Hai, Bach Dang, Cao Xanh.

Cam Pha is less affected by sea level rise. The area is inundated. They are only narrow strips (from 100-200m) located near the sea on the bank of Cua Ong, Cam Thinh, Cam Son, Cam Thuy.

Tab. 3. Flooding areas in Quang Ninh coastal area by sea level rise (km<sup>2</sup>) [5]

Natural area (km <sup>2</sup> )	Flooded areas with sea level rise scenarios (km <sup>2</sup> )			% of flood area corresponding to sea level rise		
	50cm	70cm	85cm	50cm	70cm	85cm
6 102.3	216.10	287.19	503.29	3.54	4.71	8.25



Fig. 3. Quang Ninh flood risk map [5]

Salinity intrusion due to climate change, sea level rise, not only occurs to surface water (mainly in estuaries and low lying terrain), but also to underground water, especially aquifers that have water supply from river or sea water or have a direct hydraulic relationship with surface water.

Due to the geological, topographical and hydrological characteristics, the surface water intrusion in the coastal areas of Quang Ninh is not high.

In the study area, sea water and groundwater (especially the Holocene aquifer and Pleistocene

aquifer) have a direct hydraulic relationship, so when the sea level rises, the marginal salinity of groundwater will move towards the mainland, salinity intrusion increased. This means that fresh water in part of the salinated land is degraded, and water quality and quantity are reduced, ability to provide water for living and production is decreased. However, the saline intrusion effects did not significantly alter the area's potential for groundwater supply due to the presence of groundwater in the saltwater area and the source of water supplied to the area mainly from Surface water. Therefore, the long-term supply of water for ensuring sustainable development for Quang Ninh is also an issue, especially in the context of climate change.

#### ***2.5. The main economic and structural activities affected Quang Ninh***

Economic activities - mainly affecting the environment and sustainable development of the area, affecting the lives of people as well as other economic activities in the area of Quang Ninh mainly coal mining activities. These activities change the natural conditions as well as the living

environment of the area and directly affect the operation of geological processes and phenomena. At present, Quang Ninh mainly uses open-pit and pit coal mining technologies. The creation of open coal mining sites as well as underground mining lines as well as the formation of waste dumping sites have caused the following regional variations:

- Changes in stresses in the rocks due to open excavation as well as the formation of buried furnace line in the rock. As a consequence, there is a decreased crack system along the surface of the open sloping mine, which causes the risk of sliding the mine's edge and destabilizing the walls of the coal mines.

- The creation of dumps on a large area increases the load on a large area, along with pit systems as well as open-pit mining sites that deform the soil surface, causing the risk of slipping, slaughter and sabotage of works on the face. Figures 4 and 5 are cracks formed by the impact of the tailings pit and the mining network at the bottom causing the Khe Cham mine site in Quang Ninh.



Fig. 4. A crack in siltstone and sandstone formed by the impact of the tailings pit and the mining network near Khe Cham coal mining site in Quang Ninh.



Fig. 5. Cracks in siltstone and sandstone formed by the impact of the tailings pit and the mining network near Khe Cham coal mining site in Quang Ninh.



Fig. 6. Mud flows from Mong Duong coal mine

- The formation of a system of dumping sites along the mountain side running parallel to the coastal land has created the risk of sliding, making conditions for the formation of streams of mud and rocks, threatening the safety of people's lives in the foot of the dumping ground.

From the analysis above, hilly terrain areas in Cam Pha, Ha Long and Mong Cai have developed the processes and geodynamic phenomena quite strongly in the condition of gas conversion. The current and future climate change (temperature increases from 3.1 - 3.5<sup>0</sup>C and rainfall increased from 5.7 to 9.4% as forecast), along with the process of exploiting and using land is not reasonable, disrupt the nature balance due to the economic activities, the intensity of the activity of exogenous geological processes and phenomena relating to surface water, groundwater (slides, erosion, mud and rock flood, etc.).in the research areas will be more and more powerful, not only

affecting people's life, but also causing difficulties for human's economic activities and construction such as coal mining, extraction of building materials, road works or construction works, ....

The manifestation of climate change is not only in rising temperatures and in precipitation, but also in changes in rain and wind patterns due to extreme weather patterns. In the context of climate change, the frequency of occurrence of tropical low pressure, more storms, heavy, intense intensity, prolonged, frequent rain occur. These are factors that promote the formation of large surface currents, strong underground flows, coastal currents and the increasing frequency of sea waves, marine activity. The tide has also become more complex with greater amplitude, not only causes slides, erosion, rock and mud floods quick soil in dumping sites, etc. in the high terrain mountainous areas, but also the operation of the processes and geosynthetic dynamics of coastal zones in studied

areas such as river bed erosion, erosion and sedimentation of the coastline, estuaries are increasingly developing

## **2.6. Solutions to ensure the sustainable development for Quang Ninh area**

### **1. Mong Cai - Hai Ha area**

Coastal areas which have the approximately 1m altitude terrain need to be zoned and leveled to extend the area for developing economy and people's livelihood. The leveling materials can be taken by sucking sand from the coastal zones, taken from hills which are studied to become leveling materials. These hills need to be carefully selected, so that it will not change the landscape area in negative ways. On the other hand, it will add land for urban areas

The designing ground elevation for the area of Mong Cai and Hai Ha should be determined according to the terrain level of each area. However, for coastal zones with terrains of less than 1 m, when planning construction of non-permanent houses and industrial parks, the planned ground level shall not be lower than 2.5m. Should not be too large planning will cause many inadequacies for the construction in general and the ability to drain water in particular. The design roads should be designed to the highest suitable to the regional terrain, ensuring adaptation to climate change and sea level rise in the future. The design of the route along the coast will have a dual effect, in addition to the traffic, it can create sea levees in the future.

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Because the Southeast areas of Mong Cai and Hai Ha have low terrain, in terms of sea level rises will be flooded, according to the climate change scenario. Therefore, researches should define the appropriate space for the construction of sea dike system as needed while planning construction material resources to serve the dyke construction.

Water supply for this area is mainly from surface water sources, due to limited groundwater resources, many areas are saline. Groundwater contained in the cracks of the continental formation has limited reserves, can only provide small, local water.

### **2. Cam Pha**

The water supply for Cam Pha and Ha Long townships must be taken from surface water, because of groundwater infiltration. Underground water in the fractures of the original strength sedimentary formations is quite good, but only in small scale and local. In order to ensure the security of water resources for daily life and economic development, it is necessary to study in the future when closing coal mines, renovating open-pit mines into fresh water reservoirs, land for living, economic development and tourism. For underground mines, there should be research to create artificial groundwater reservoirs to supply the urban areas of Cam Pha, Ha Long and adjacent areas, which are in shortage of fresh water, especially in the condition climate change and sea level rise.

Developing mangrove forests and coastal land to improve the environment, resist the climate change and sea level rise; Planning properly aquaculture areas.

## **3. Conclusions**

According to the published documents as well as the actual occurrence in the area, climate change and sea level rise have promoted the operation of geological processes and phenomena, causing flooding and saline intrusion, affecting negatively the socio-economic development as well as the lives of people in Quang Ninh areas. We need appropriate solutions for prevention and mitigation of adverse impacts of the climate change. and sea level rise.

Economic activity that is mainly coal mining has caused changes in stress state in the soil, affected the stability of the area in general and of the works in particular. Changes in stress state should be taken into account when conducting



economic and structural activities. Due to the lack of surface drainage and waste water in the waste disposal site, there is a high risk of geological hazards such as landslides and mudflat, especially in the context of climate change.

In order to mitigate adverse impacts of climate change, sea level rise as well as economic and structural activities to the sustainable development of the area, the need of constructing the drainage system on the surface and in the waste dump; Rational planning of mining operations after closure of mines, especially the need to study the construction of artificial lakes as well as the ability to store underground water in the pit and open pit mining site to provide water long term for the urban area.

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