DEM and vulnerability classifications about Balchik test site according EU SCHEMA Project

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The paper is devoted to DEM and vulnerability classifications about the Balchik test site according to the EU SCHEMA Project. A brief overview of the previous studies on the tsunami hazard along the Bulgarian Black Sea coast is made; the factors and indicators of coastal structure vulnerability, EM construction and use of GIS database for vulnerability assessment are described.

1. Previous tsunami investigations in the Black Sea

The continuous research of the Black Sea tsunamis started in Bulgaria at the early 80-ies of the XX century, creates interest and curiosity in the scientific community abroad. The first publications indicated that the Black Sea tsunamis are possible phenomena have been followed by the participation of the Bulgarian specialists in the GITEC Project of EU (1992-1995). During the execution of this project many new and unknown facts about the observed and supposed tsunamis in the Black Sea and have been discovered. The tsunami research in Bulgaria has been developed in different directions:

- New data and homogeneous catalogue (as part of the standardized GITEC catalogue) has been compiled [5,9,10];
- Tsunamigenic sources and natural vulnerable areas have been outlined [4,6];
- Ray refraction analysis and tsunami energy dissipation/concentration have been performed for the whole Black Sea area;
- Special vulnerability analysis has been performed for some areas and test site areas [6,7];
- Fractal properties of the tsunami in the Black Sea according the bottom and coastal geometry [11];
- First attempts of the tsunami zoning for the whole Black sea at large scales and in case of not completed information have been executed and rough schemes created, assessing the expected average run-ups and attack velocities of the tsunami to the shore, based on the average repeated recurrence time established by the real data [10, 12, 15, 16, 17,18];
- Original equipment about the tsunami laboratory generation and physical modeling investigations has been patented [2];
- Paleotsunami deposits have been discovered for the first time on the Black Sea coasts [13,14].

2. SCHEMA Project – general scope

SCHEMA is the acronym of the Scenarios for Hazard-induced Emergencies Management Contract No: 030963 with EC of the PF6 Priorities (Space). Duration – 36 months, 12 Partners organizations from France, Portugal, England, Italy, Greece, Morocco, Turkey and Bulgaria

The Project is constructed by several working packages (WP's):

- the first one is related to the Lessons learnt by the previous experience and modeling possibilities and vulnerability analysis
- Other WP's include several (5 test site areas - Morocco: Rabat region; Bulgaria : Varna region on Black sea – Balchik town is a representative sample; France: Mandelieu, Cote D'Azur; Portugal: Setubal; Italy: Catania, Sicily, where different methodologies about tsunami modeling and vulnerability assessment will be performed. The main tasks of the Project is to satisfy the end-users requirements about the possible prevention and protection actions to the population of the threaten test sites.
- The last WP's are related to the management of the Project and the dissemination of the results obtained - Large knowledge exchange and massive people information is intended to the final stage of the project (Workshops, educational materials to the decision makers and the public, mass media involvements, etc.)

The Bulgarian participation in the SCHEMA Project is represented by the Space Research Institute (SRI) which is a regular partner to the Project. Specialists with different abilities from different (outside SRI) organizations (GFI, SW University, PLD observatory, CDA, etc.) play important role in the work performed. The initial items definition (test-site area, data and catalogues (earthquakes, surface and underwater landslides as possible triggers of tsunami), data bases, space images and their use to the vulnerability studies, etc.), end-users requirements and research activities intended are parts of the intended activities.

The first year workshop on the Project execution took part in Bulgaria – Golden sands – 12-17 June, 2008 and had a reasonable success.

3. Case studies about Bulgarian coastal tsunamis III-rd (Demetrious Kalatious) (I[st]?) century BC case – IX-X tsunami intensity (Papadopoulos-Imamura (P-I) scale)

"Ancient town Bisone (Greek colony) sank in the sea waters" (Strabo). Major earthquake (M~8), accompanied by huge slides and large inundation (probably tsunamis). "The whole" ancient city (most probable – the port and the facilities) went under water. The rest part of the town was moved on the top hills. Paleotsunami findings.

543AD case – VII tsunami intensity (P-I scale)

Earthquake (magnitude~7.5), probable local tsunami, activated landslides, destroyed and buried the Cibele temple. Possible paleotsunami findings.

31[st] March 1901 earthquake and tsunami – V tsunami intensity (P-I scale)

Earthquake of magnitude M=7.1 occurred in the sea. Large destruction in the epicentral area (more than 5 villages and small towns have been affected; more than 830 houses damaged.). Aftershock sequence lasted more than 7 years.

Land subsidence and landslides (probably submarine as well) occurred. Rockfalls were reported. A witness reported a sea level rise of about 3 meters at the port of Balchik, recognized as tsunami.

The case of 7th May, 2007 – V tsunami intensity (P-I scale)

Northeast Bulgarian coast – nonseismic origin (possible underwater turbidities). Data about withdrawal and inundation – frequency of the phenomena (3-5 – 6-8 minutes) are collected. Data about the water peculiarities consequences – observed turbulences, currents and water boiling supports the used models. Data about the consequences – moved boats, tetrapodes and other items also have been assessed. [19]. (The detailed description - see later on)

The systematic data of the parameters of these events are presented at Table1 and Table 2.

TABLE I
The tsunami cases to the North Bulgarian Black Sea coast:

Time/parameters	Events	Tsunami intensity
Ist (III?) century BC multihazards event	Earthquake, slides, regional inundation	IX-X tsunami intensity Papadopoulos -Imamura (P-I) scale
543AD multihazards event	Earthquake, slides, local inundation	VII tsunami intensity (P-I scale)
31st March, 1901	Earthquake, slides, rockfalls, local inundation	V tsunami intensity (P-I scale)
7th May, 2007	Nonseismic origin, only frequent water level oscillations	V tsunami intensity (P-I scale)

The suggested scenario for the North Bulgarian Black Sea coast is based on the 1901 case (**referent event** - as a better studied and the most informative and reliable case), intend a multihazard assessment, possible inundation areas outlines, risk mapping and possible evacuation roads indication.

TABLE II
The known tsunami generating events to the North Bulgarian Black Sea coast

Year	Latitude E	Longitude N	Depth [km]	M	Macro Int. (EMS)
Ist (III?) c. BC	43,4	28,4	20	8,0	IX-XI
543	43,5	28,3	20	7,6	IX - X
1901	43,4	28,6	14	7,2	IX - X
2007	43,1	28,6	0		slide(?)

The intended scenario earthquake has the following parameters:

Epicenter location: 43,2E; 28,6N; Depth-15; Epicentral intensity – X EMS; Magnitude: 7.2; Vertical displacement: 2-3 meters; Strike: E-W (1st variant) and NE-SW (2nd variant). This scenario is based on the event of 1901 as best studied earthquake and its consequences.

The formulation of the vulnerability criteria following the IADB (Inter American Bank of Development) methodology is the next important task of the test-site activity and assessment.

During the last years some new developed methodologies have been tested for the North Bulgarian Black Sea coast. The IADB methodology needs a special scheme about the factors and indicators recognition. After our research and investigations we developed and accommodated the indicators tables, which contains data and information about the main indicators and factors for vulnerability assessment [21,22]. For example the following list was constructed using the approach of the IADB:

4. VULNERABILITY - (factors and indicators)

Physical/demographic

(V1) Density of population– av.
(V2) Demographic pressure – p.av.
(V3) Unsafe settlements – av.
(V4) Access to basic services –p.av.

Social

(V5) Poverty level – p.av.
(V6) Different social groups; (V6) Literacy rate – (changed) - p.av.
(V7) Attitude – nav.
(V8) Access to services; (V8) Decentralization – (changed) – p.av.
(V9) Number of med.personel/per inhabit.; (V9) Community participation – (changed) - p.av.
(V10) Number of staff (civil defence, fire brigades) – (new) – av.

Economic

(V10) Local resource base - eliminated
(V11) Diversification – nav.
(V12) Small businesses – nav.
(V13) Accessibility – nav.

Environmental

(V14) Biodiversity – (new) – av.
(V15) Pollution - new – av.
(V14) Area under forest – eliminated
(V15) Degraded land - eliminated
(V16) Overused land - eliminated

EXPOSURE

Structures (vulnerability functions)

(E1) Building and facilities – nav.
(E2) Lifelines (power and water supply) – av.
(E3) Roads – av.
(E4) Railways-av.
(E5) Ports – av.

Population

(E6) Total resident population – p.av.(due to the seasonal changes)

Economy

(E7) Local gross domestic product (LGDP) – nav.

In *this* list:

av. means available data and information about this parameter
nav – means not available data about this parameter
p.av. – means partially available data and information.

After the accommodation, the most difficult task is to determine the values of the different factors and indicators, as well as the weighting coefficients and scaled values.

The statistics of the vulnerable elements (natural and man-made) is important input information, which is still under collection and clarification.

To the moment only the inventory table about the natural tsunami vulnerable elements is constructed – Table 3.

TABLE III
Inventory data about the natural tsunami vulnerable elements on the test site: (BG-ROM boundary-Galata horn)

Natural elements/ Parameters	Total length/area	% vul. by 3m. tsunami (run-up height)	% vul. by 5m. tsunami (run-up height)
Coast line	118.0 km	73.0%	84.0%
Lowlands	73.8 km^2	94.1%	97.2%
Bays	20.0 km	42.3%	48.7%
Lagoons	9.1 km^2	~98.1%	100.0%
River beds	54.8 km2	~92.6%	99.7%

5. DEM construction

The topography of the test-site has been represented by DEM and satellite images. A Quick Bird satellite image locations and GPS field check points are shown in Figure 1.

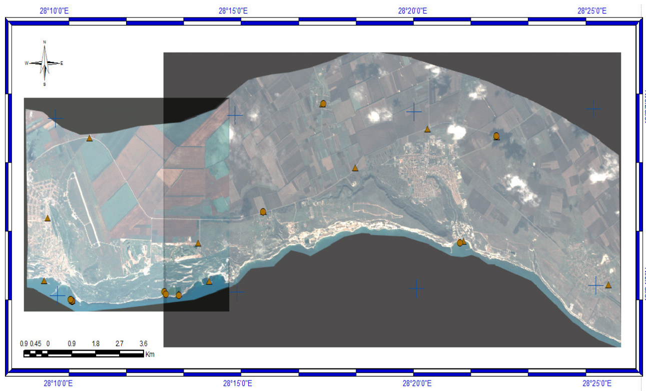

Fig.1. Quick Bird satellite image locations and GPS field check points

For the production of the DEM along the coastal zone of interest, a set of topography maps of 1:5000 scale were used – Figure 2.

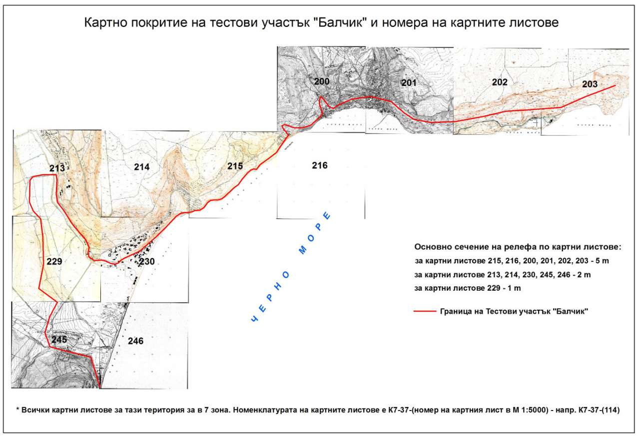

Fig.2. The topography maps of 1:5000 scale used for the production of the DEM along the coastal zone of interest (red line).

The high-resolution DEM for Balchik, in ArcGIS is shown in Fig. 3, while the DEM with 3 m (red) and 7 m (yellow) hypothetic inundation is illustrated in Fig.4.

A set of satellite images were collected to be used for the topographic representation of the test-site. Some of these satellite images are shown in Figures 5 and 6.

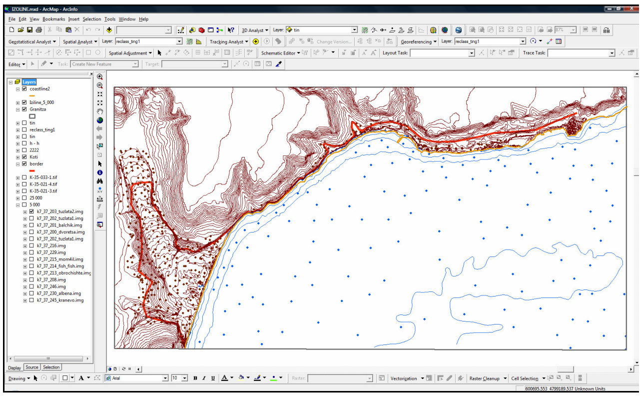

Fig.3. The high-resolution DEM for Balchik, in ArcGIS.

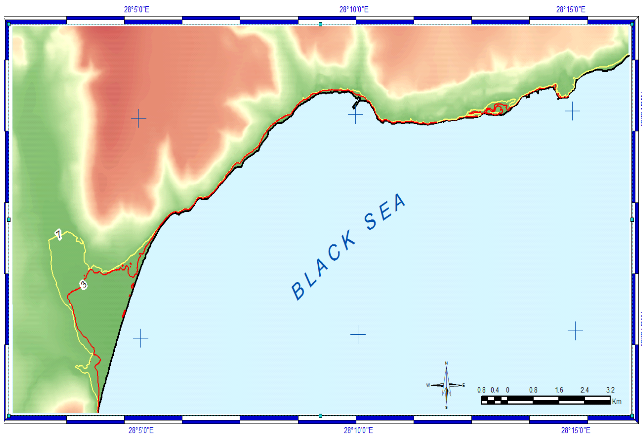

Fig.4. The DEM with 3 m (red) and 7 m (yellow) hypothetic inundation.

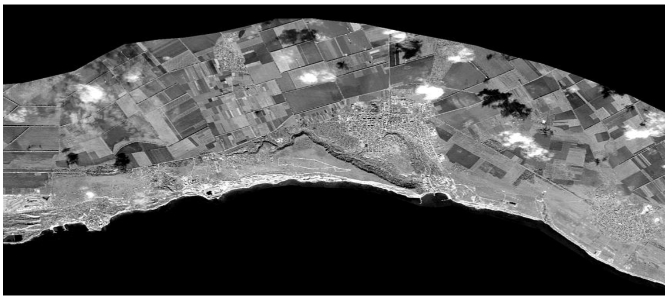

Fig.5. Panchromatic satellite image of the Balchik test-site.

Fig.6. Multichanel satellite image of the Balchik test-site.

6. GIS database for vulnerability assessment

From field inspection in the test-site of Balchik performed by the SRI-BAS staff it became possible to map the main vulnerable objects (Fig. 7).

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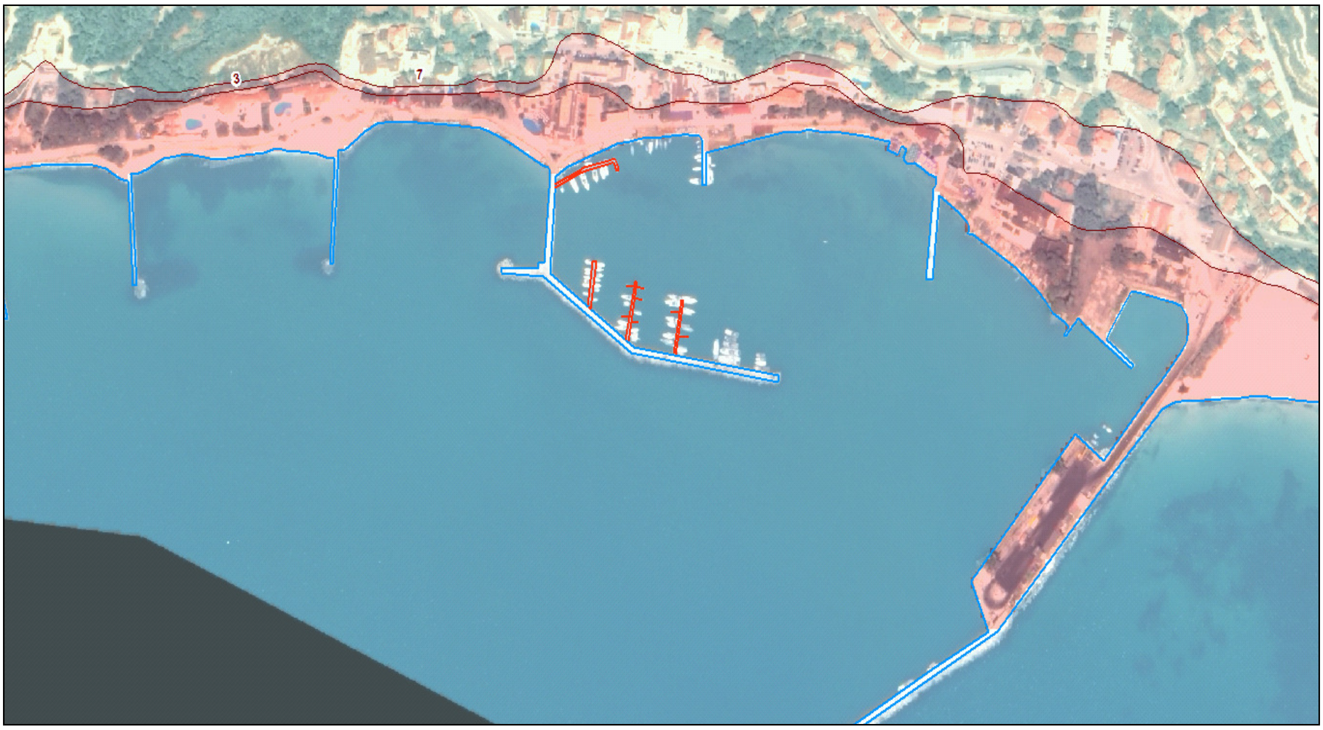

Fig.7. The possible inundated areas (3 m and 7 m) and vulnerable objects.

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