DEPARTMENT OF CIVIL ENGINEERING
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DELOS WP 1.1 Inventory on LCS, detailed description

According to DELOS WP 1.1 an inventory for existing low crested structures (LCS) must be established. As low crested structure we mean structures designed to be submerged or regularly overtopped by waves. The detailed inventory (described below) concerns shore parallel structures including shore-attached structures, which are perpendicular to shoreline if part of the scheme. This inventory will be established through a digital questionnaire located at www.delos.dk

The inventory is established in the following way:

- A brief description is given for each LCS (another document). This description should be given for all kinds of LCS.
- Some structures/locations are selected for further investigations
- A more detailed description is given for the selected structures/locations (this document). This part shall focus on shore parallel structures including shore-attached structures, which are perpendicular to shoreline if part of the scheme.

Both the brief and the detailed descriptions will be presented on www.delos.dk

For each structure the following information should be given.

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How to use this document

In this document, you can give a detailed description of a specific LCS. The description must be completed within this digital document. Just type the text in the tables, insert relevant pictures, drawings, sketches etc. and save the document. Only relevant information should be included in the document; existing non-used tables, sketches etc. present in this document must be deleted. The existing figures etc. are meant to be guidelines that can be changed for a specific environment. But please keep the structure of the document intact.

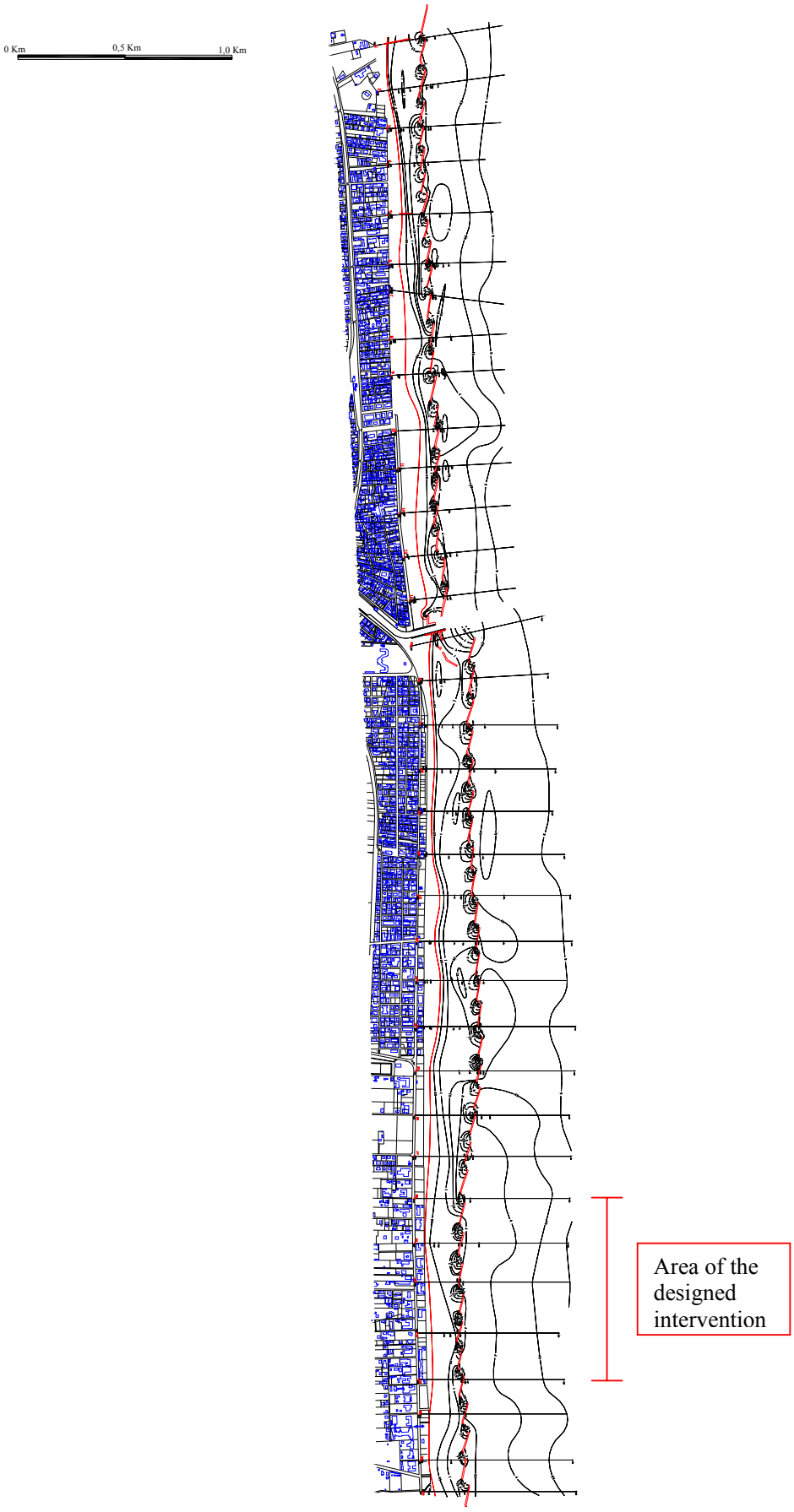
When completed, please attach the document to an email and send it to i5mkr@civil.auc.dk.

The filenames for the documents must include the participant code, the Country Code (as used on the Internet for Country Code Domains) and a Location-number between 001 and 999. It is very important that the same Location-number is used as for the brief description. The letters "det" must also be included to indicate that the detailed version of the questionnaire is used. The filenames for UB collecting information from East Italy (see special Country Code below) will therefore be "UB_EIT_det_001.doc" till "UB_EIT_det_999.doc". Each participant must provide a map of the country showing all the locations of the sites of interest, the Location-numbers must appear on this map.

Inputs come from:
UPC: Spain (Country Code ES)
DHI: Denmark (Country Code DK)
MOD & UR3: West Italy (Country Code WIT)
UB: East Italy (Country Code EIT)
AUTH: Greece (Country Code GR)
INF: Holland (Country Code NL)
UCA: non European LCS by literature study (Country Code nonEU)
UoS: U.K. (Country Code UK)

A: Formalities

Participant code and who to contact.	UB_EIT EMANUELA CLEMENTI
E-mail	emanuela.clementi@mail.ing.unibo.it
This date (today, mm:dd:yyyy) and revision number (A..Z).	02:15:2003
Location of LCS.	BELLARIA-IGEA MARINA
Start date, length and/or end of works. Have there been any later changes? If so, when?	Start date: 1965-1968 Changes: 1978-1998
Design life - the minimum length of time the beach management scheme is designed to last.	
Which tools and regulations are used for the design formulae (mathematical models, model tests, engineering experience, standards, recommendations).	mathematical models, engineering experience, standards
Who fund the work (e.g. Public Administration or private company)?	Public Administration
Costs.	

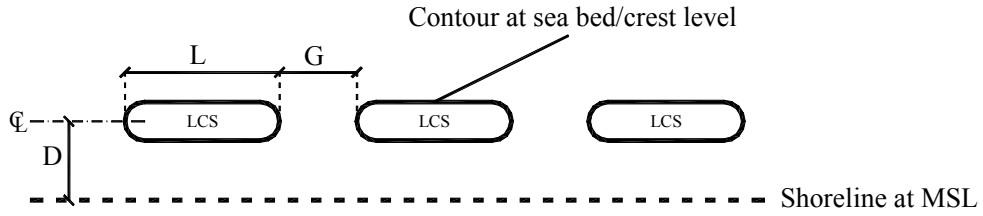

0 Km
0,5 Km
1,0 Km
Area of the designed intervention

B: Geometry and construction materials

B1 System layout (aerial view)

Are shore attaching structures present (e.g. groins)?	☐Yes ■No
Are emerging head islands present?	☐Yes ■No

The following sketch concerns only shore parallel LCS; if the layout is different you must insert another sketch and specify parameters like the ones suggested. If a picture is available please insert it too.



The typical layout is given at Sea Bed (index SB) and at Crest Level (index CL).

Parameter	Description	Fill in box	Unit
D	Distance from shoreline	100 (North side) 200 (South side)	Meters
L_{SB}	Length of LCS at sea bed	About 100	Meters
L_{CL}	Length of LCS at crest level	About100	Meters
G_{SB}	Gap between LCS at sea bed	About 25	Meters
G_{CL}	Gap between LCS at crest level	About 25	Meters
n	Number of LCS in system	54	

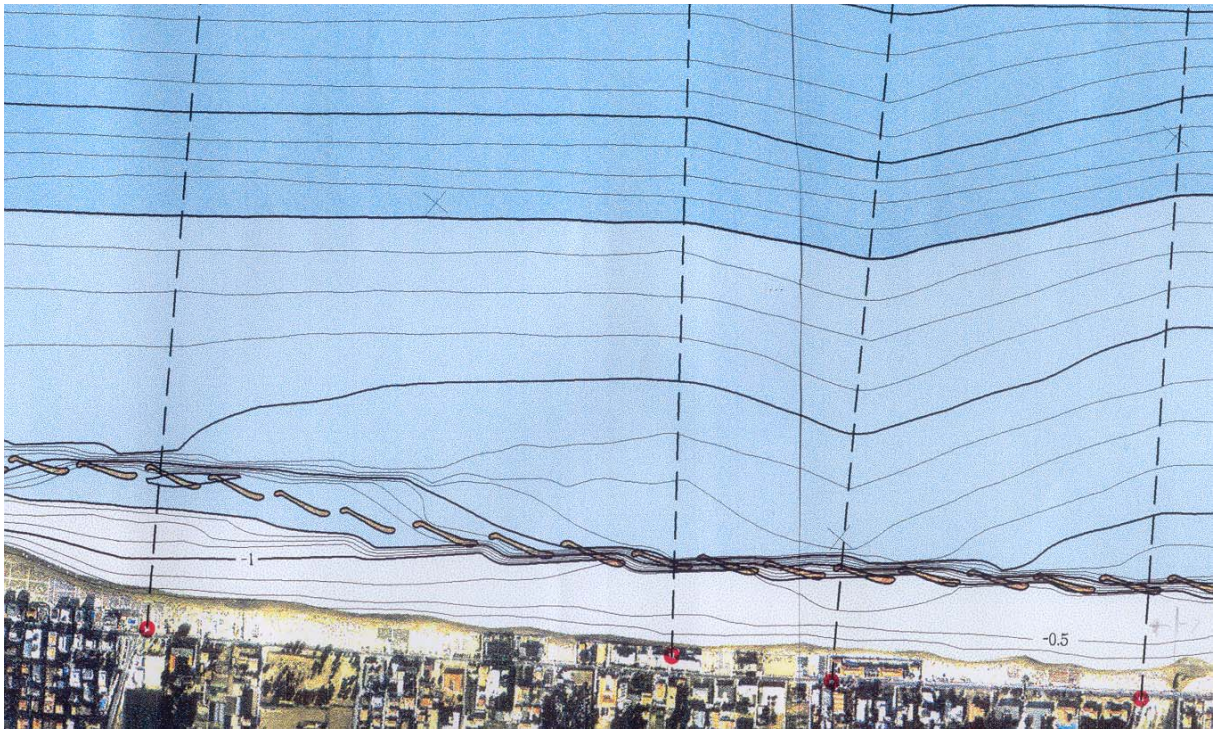
Remarks

54 elements, about 100 m long with a little harm, with a different orientation, about 20 m long. Distance from the beach around 100 m in the North side and 200 m in the South side. Orientation to the normal to the coast line about 75°. Gap's length: 25 m.

Changes during the years: narrowing of gaps, recharge of barrier with stones, extension of barrier through submerged sections in gaps.

B2 Bathymetry of sea bed and beach

Please insert a dimensioned sketch if possible.



Scale 1:10000

Description of bathymetry when LCS were build

Is detailed information (measurements) available? If so, please explain.

Bellaria–Igea Marina boundaries are: Rimini (South) and Rubicone river (North).

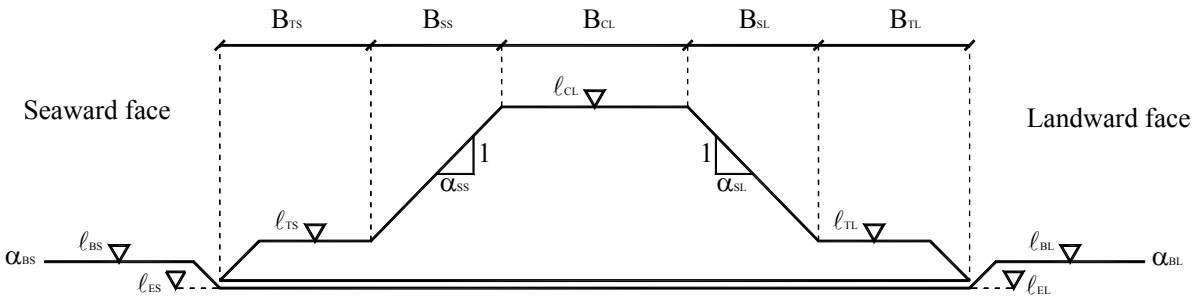
The coast of Bellaria–Igea Marina is characterized by a strong shoreline receding, particularly due to the construction of Rimini harbour in 1920-1930, then to the less fluvial supports from Foce d'Uso and Marecchia rivers, and to subsidence.

Off-shore bathymetry is quite uniform: steepness is about 1:200.

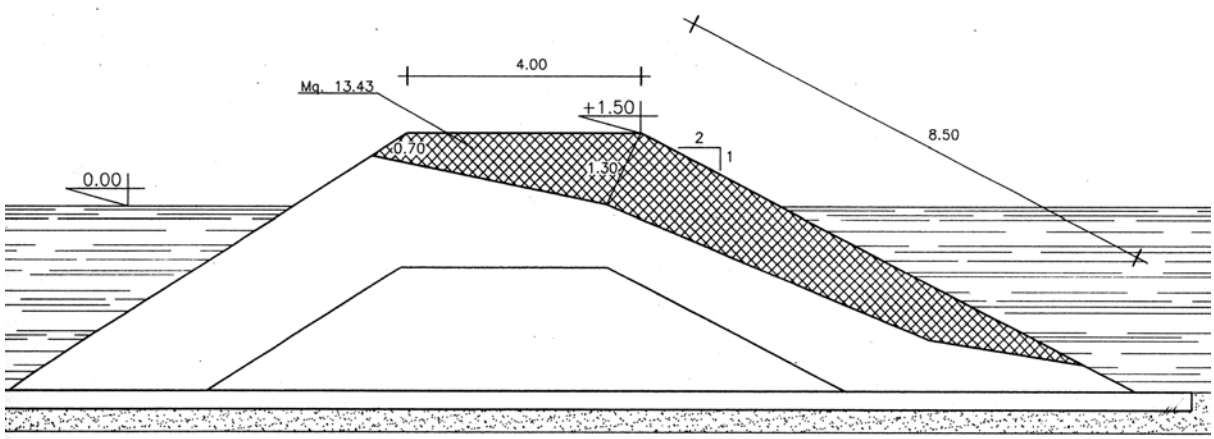
On-shore steepness is about 17:1000.

B3 Trunk cross section/contour geometry – outer profile

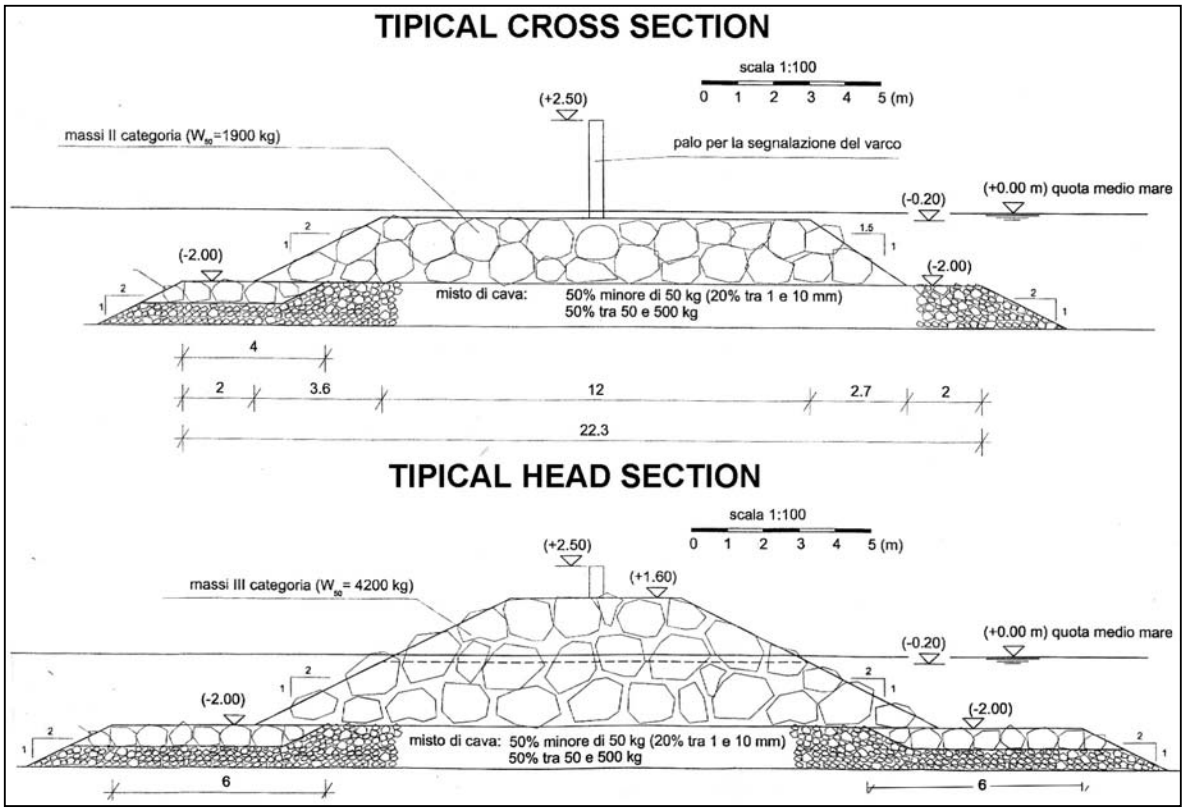
If shore attached structures perpendicular to shoreline are present, please insert a sketch with typical longitudinal section and typical selected cross sections. Specify parameters as the ones given below. If the layout does not fit the following sketch please insert another sketch.



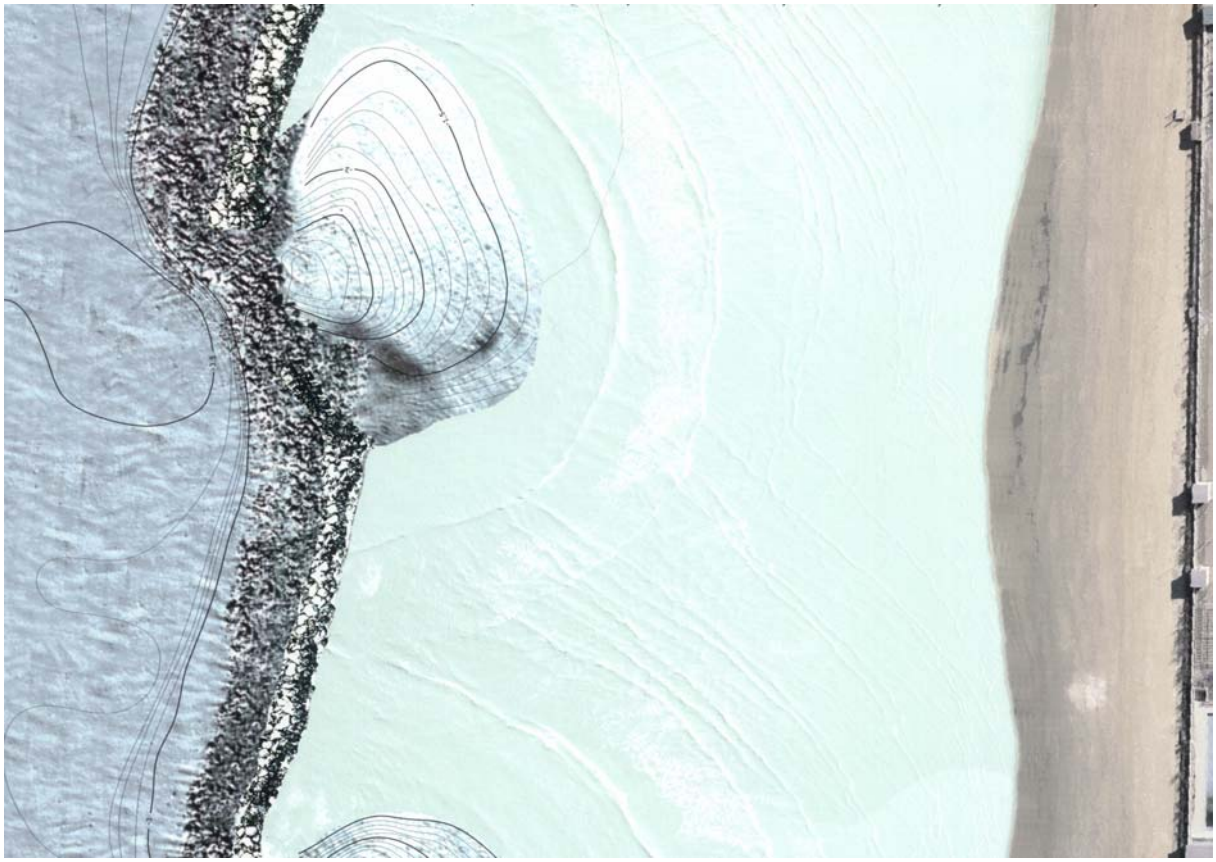
Typical cross-shore section of emerging breakwater along Emilia Romagna coast:



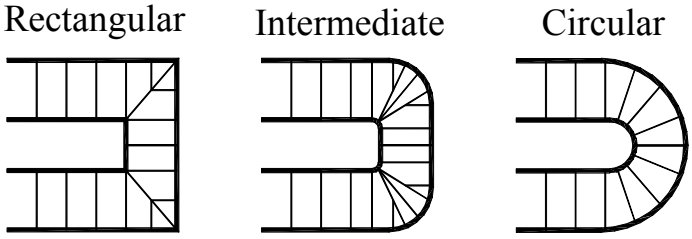
Parameter	Description	Fill in box	Unit
α_{BS}	Steepness of sea bed, seaward	5:1000	
α_{BL}	Steepness of sea bed, landward	17:1000	
α_{SS}	Steepness of slope, seaward		
α_{SL}	Steepness of slope, landward		
ℓ_{BS}	Level of sea bed at seaward toe		Meters
ℓ_{ES}	Level of excavation, seaward		Meters
ℓ_{TS}	Level of toe, seaward		Meters
ℓ_{CL}	Level of crest	+1.20	Meters
ℓ_{BS}	Level of sea bed at landward toe		Meters
ℓ_{ES}	Level of excavation, landward		Meters
ℓ_{TS}	Level of toe, landward		Meters
B_{TS}	Width of toe, seaward		Meters
B_{SS}	Width of slope, seaward		Meters
B_{CL}	Width of crest	4.0	Meters
B_{SL}	Width of slope, landward		Meters
B_{TL}	Width of toe, landward		Meters



Remarks (e.g. different layout along shoreline, other important parameters). Changes in the structure and in particular in the roundheads are shown in the following figure.



B4 Round head contour geometry

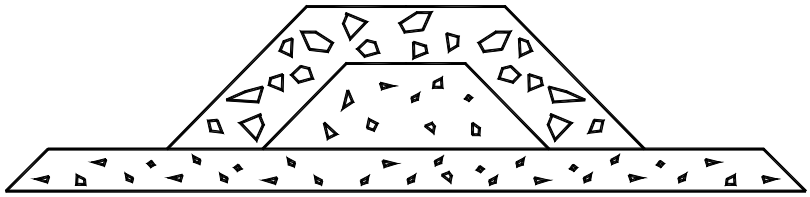


What is the shape of the round head?

- ☐ Rectangular
- ☐ Intermediate
- ■ Circular

B5 Description of layers

Please insert a dimensioned sketch with the typical cross-section composition.



For each layer, please provide the following information.

ARMOUR

Parameter	Description	Fill in box	unit
	Material (e.g. quartzite, concrete)	Limestones and calcareousrocks	
	Shape of blocks (e.g. quarry rock, sea stones, cubes)	Quarry rock	
W	Weight of blocks	II CAT:1900 III CAT: 2400	Kg
ρ_r	Mass density of material		Kg/m^3
D_{n50}	Nominal diameter		Meters
Gr	Grading of the material (D_{85}/D_{15})		
	Geotextile between layers?	☐ Yes ■ No	

BEDDING LAYER

Parameter	Description	Fill in box	unit
	Material (e.g. quartzite, concrete)	Limestones	
	Shape of blocks (e.g. quarry rock, sea stones, cubes)	Mixed quarry	
W	Weight of blocks	50% weight < 50 50% weight 50-500	Kg
ρ_r	Mass density of material		Kg/m^3
D_{n50}	Nominal diameter		Meters
Gr	Grading of the material (D_{85}/D_{15})		
	Geotextile between layers?	☐ Yes ■ No	

Remarks (e.g. details on geotextile)

B6 Construction method

How have the stones been placed?

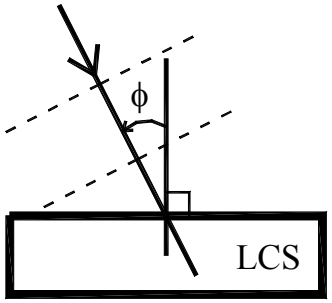
- ☐ Dumped with barges
- ☐ Placed with barges
- ☐ Land based operation
- ☐ Other:

Sequence of operation.

- ☐ Construction started upstream
- ■ Construction started downstream

C: Local meteomarine conditions at the structure

C1 Waves



Parameter	Description	Fill in box	Unit
H_S	Design significant wave height		Meters
T_P	Design peak period		Seconds
ϕ	Design wave incidence angle		Radians

Remarks (provide information on wave statistics and wave spectra if available, e.g. H_S corresponding to return periods 1 month, 1 y, 10 y, 50 y. Please specify the source of the data)

C2 Water levels

Tidal water level variations

Parameter	Description	Fill in box	Unit
HAT	Highest astronomical tide level		Meters
MHWL	Mean tide high water level	0.4	Meters
MWL	Mean water level	0.0	Meters
MLWL	Mean tide low water level	-0.4	Meters
LAT	Lowest astronomical tide level		Meters

Water level statistics (If available, please provide information on design water level and tide and surge generated water levels corresponding to return periods 1 month, 1 y, 10 y, 50 y)

C3 Current

Tidal currents

Description & statistics if available

Littoral current direction: N-NW.

Surge generated currents

Description & statistics if available (e.g. mean velocities as function of water depth/distance to shore line)

D: Sea bed and beach characteristics, incl. sediment transport

Description of the coast (e.g. bar type coast with gentle slope or plane coast with steep slope)

It’s a bar type coast with gentle slope.

D1 Sea bed material at surface

Parameter	Description of sea bed material	Fill in box	Unit
	Material (e.g. quartzite)	Natural sand	
ρ_r	Mass density of material		Kg/m^3
D_{n50}	Nominal diameter grain size		Meters
Gr	Grading of the material (D_{85}/D_{15})		

Remarks (provide grain distribution if available)

See the following table.

Depth (m)	Sand %	Clay %	Diameter (m)	Standard Dev.	Asymmetry	Kurtosi
0.0	99.6	0.4	0.178	0.59	0.02	0.87
-2,5	96.6	3.4	0.105	0.38	0.15	0.98
-4	97.5	2.5	0.113	0.39	0.02	0.96

D2 Beach material at surface

Parameter	Description of beach material	Fill in box	Unit
	Material (e.g. quartzite)	Natural sand	
ρ_r	Mass density of material		kg/m^3
D_{n50}	Nominal diameter grain size		Meters
Gr	Grading of the material (D_{85}/D_{15})	2.43	

Natural supply?	■ Yes ☐ No
Supplied by beach nourishment?	■ Yes ☐ No

Remarks (provide grain distribution if available)

D3 Sediment transport

Description of the sediment transport (e.g. direction and amount of transport, distribution over the coastal profile)

Sediment transport direction is from South to North, but there's scarcity of material in circulation.

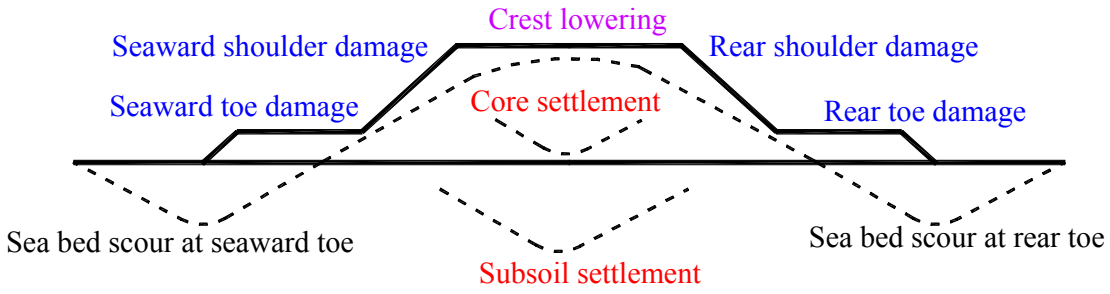
During the last years, as a consequence of changes in the reefs structure, waves motion decreased, so there were deposition of fine grain size sediments on the landward side of the structures. Between the structures and shoreline the bathymetry is everywhere about –1 m..

The following parameters must be completed only if artificially nourished and different form sea bed material.

Parameter	Description of artificial sediment	Fill in box	Unit
	Material (e.g. quartzite)		
ρ_r	Mass density of material		kg/m^3
D_{n50}	Nominal diameter		Meters
Gr	Grading of the material (D_{85}/D_{15})		

E: Structural performance

E1 Definition of failure modes



Please e-mail a sketch with dimensions of LCS cross-section when it was build compared to the appearance now (like the figure of failure modes) if possible. If so, please type the filename in the box.	

In the following please specify damages by failure mode (see figure of failure mode definition) and amount of damage. If you know the reason for the problems/failures (e.g. extreme wave climate/water level), please type it in the description boxes.

E2 Materials

Problems caused by deterioration?	☐ Yes ☐ No
Problems caused by breakage?	☐ Yes ☐ No

Description of the condition of the materials

E3 Settlement of the structure

Description of settlements of core/subsoil (e.g. instabilities in foundation, internal erosion). Please specify settlement in meters.

E4 Local erosion of sea bed/scour

Description of erosion/scour by roundheads (please specify scour depth)
Description of erosion/scour by trunk (please specify scour depth)

E5 Erosion and instability of slopes, shoulders, crest and toes

Stage of damage
☐ No or marginal damage
☐ Moderate to severe damage
☐ Failure

Description of displacements of structural material (provide sketch if possible)

E6 Damage parameters

The definition of a displaced unit is, when a unit is displaced by more than D_{n50}.
Try to give an estimate of the following damage parameters relevant to armour.

Parameter	Description	Fill in box	unit
The relative number of displaced units	$D(\%) = \frac{n_d\,(\text{number of displaced units})}{\text{Total number of units}} \cdot 100$		%
The strip displacement	$N_{od} = \frac{n_d}{L / D_{n50}}$, L is the length of LCS		

F: Socio-economic aspects

What regime of property has the coast at this site?
Private ☐, Public full free access ■ Public limited access ☐, Natural reserve ☐, Don't know ☐,
Other (please specify):

Who decided that an LCS should be built at that site?
Individual, acting for private purpose ☐
Individual, acting for public purpose (e.g. Natural park administrator) ☐
Local authority (e.g. city council) ■
Regional authority (e.g. province level) ■
National authority (e.g. ministry) ☐
Don't know ☐
Please give name of the authority whenever applicable:

What was the main motive for building the LCS?
Coast erosion ■
Inducing or maintaining recreational activity ■ please specify:
Environmental concern ☐, please specify:
Other ☐, please specify:
Don't know ☐

Was that LCS part of a larger coastal management plan?
Yes ■ please specify:
No ☐, please specify:
Don't know ☐

Public opinion on that LCS:
Construction was accompanied by public protest ☐
The public did not react ☐
Public opinion asked for the LCS ☐
Local commerce asked for the LCS ☐
Don't know ☐
Other (please specify):

Description of the coast:
Urban ☐, Densely constructed ■, Scarcely constructed ☐, No apparent construction ☐
Are there dunes? Yes ☐, No ■
Has commercial activity changed significantly after construction of the LCS?
hotels construction: More hotels ☐, Less hotels ☐, Unaffected ☐, Don't know ☐
bars and similar construction: More ☐, Less ☐, Unaffected ☐, Don't know ☐
advertising for the area: More ☐, Less ☐, Unaffected ☐, Don't know ☐
other (specify):

Visual impact of LCS not already described in Part B: Are there parts of the LCS visible under average conditions? Poles ☐, Cables ☐, Reefs ■
Others (please specify):

Water quality changes since LCS construction
Are there episodes of water turbidity since construction?
No ■, Rare ☐, Often ☐, Permanent ☐
Were there episodes of water turbidity before construction?

No ☐, Rare ☐, Often ■ Permanent ☐
Has water quality otherwise been affected (for example, more or less detritus accumulating)?
Please describe:

How would you qualify the following recreational activities at or around the LCS? (DK = Don't know)

Fishing (recreational)	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Seafood collecting	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Wildlife watching	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Sunbathing and similar	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Scuba diving	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Sailing and similar	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Other (specify)	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐

Could you describe those recreational activities before the LCS was built? (DK = Don't know)

Fishing (recreational)	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Seafood collecting	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Wildlife watching	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Sunbathing and similar	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Scuba diving	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Sailing and similar	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐
Other (specify)	Intense ☐	Moderate ☐	Scarce ☐	Absent ☐	DK ☐

Has that LCS had an environmental impact assessment before being built? Yes ☐, No ☐, Don't know ☐
Could you give its references and location (specify)?

Has there been an economic study on that LCS,
before it was built? Yes ☐, No ☐, Don't know ☐, References:
after it was built? Yes ☐, No ☐, Don't know ☐, References:

G: Ecological aspects

What are the dominant species on the structures?

What are the dominant species in the sediment and fish assemblages around the structures?

Were any environmental changes observed following the construction of the structure (e.g. increase of water turbidity, floating algal debris)?

At Igea Marina, structures construction has been associated to a decrease of wave motion between shoreline and structures; the major change observed is a reduction of the average grain size of sediments landward. As a consequence, water turbidity also slightly increases.

H: Coastal protection performance

H1 Bathymetry and beach evolution

Description of historical beach evolution before LCS was built (10-20 years).

Erosion of the coast in the whole area mainly due to harbour of Rimini construction (1920-1930), less fluvial supports from Foce d'Uso and Marecchia rivers, and subsidence.

Description of beach evolution after LCS was built up to now.

At the beginning, the cost defence with emerging barriers wasn't able to protect the area from erosion, so from 1978 some changes were been made in the structure (narrowing of gaps, recharge of barrier with stones, extension of barrier through submerged sections in gaps).

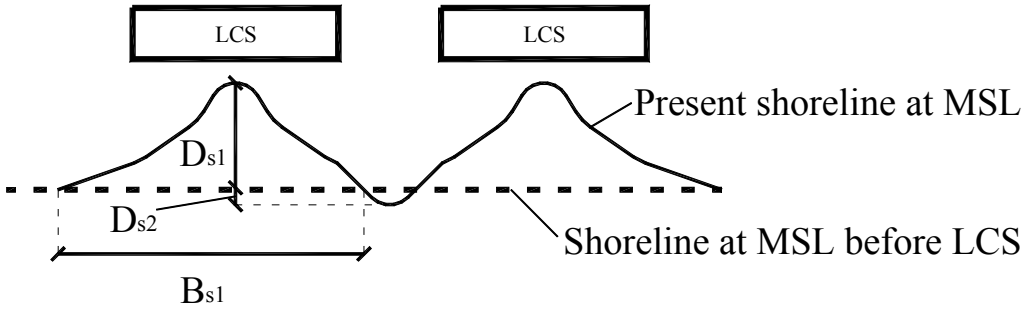
In the last years an accretion of the coast is visible in the protected area, and the subsidence decreases from 3-4 cm/year between 1984-1987 to 1 cm/year between 1987-1993.

It is interesting make in comparison bathymetry of 1998 and of 2001. In 1998, next to the reefs seaward, bathymetry is included between –2 and –3 meters depth, but in 2001 these values become about –3 meters.

Even the erosion around the openings is increasing, because of the return currents.

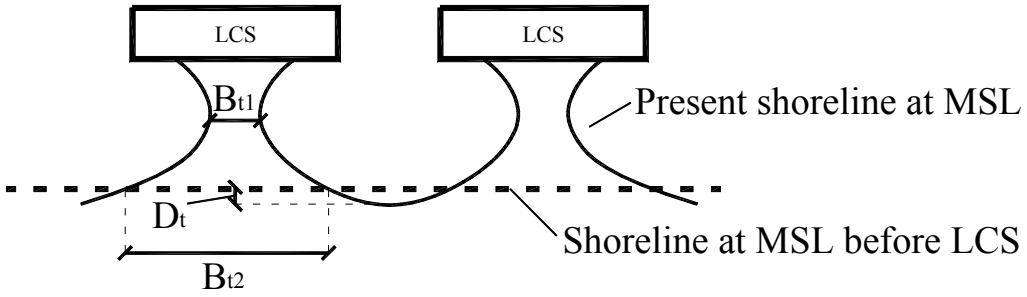
Between the structure and shoreline bathymetry is everywhere about –1 m.

H2 Salient formation



Parameter	Description	Fill in box	unit
D_{s1}	Max distance between new and old shoreline, seaward		Meters
D_{s2}	Max distance between new and old shoreline, landward		Meters
B_{s1}	Width of salient at old MSL		Meters

H3 Tombolo formation



Parameter	Description	Fill in box	unit
D_t	Distance between new and old shoreline, landward		Meters
B_{t1}	Minimal width of tombolo		Meters
B_{t2}	Width of tombolo at old MSL		Meters

H4 Renourishment

Description of renourishment (add more fill) (e.g. amount, how often)

H5 Down drift erosion

Please insert a sketch if relevant.

Description of down drift erosion (morphological impact, e.g. down drift erosion length and maximal down drift shoreline retreat)

I: Problems in general

Description of other problems/impacts • Reduction of wave motion • Reduction of the average grain size of sediments on the landward side of the structure • Erosive patterns at roundheads due to return currents through gaps • Increase in water turbidity.

Solutions:

To improve the situation of erosion and of water / sediment quality a pilot project has been designed:

- Experimental solution with 6 barriers
- Removing top layer of stones from barrier crest to leeward side in order to enhance water re-circulation through overtopping and improve water / sediment quality in the protected area
- Nourishment (70.000 m^3) along 750 m
- Works started in January 2003