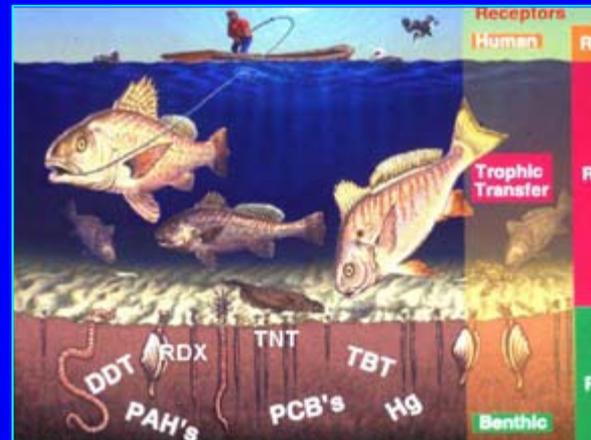


NATO/CCMS 2007 MEETING **Ljubljana, SLOVENIJA June 20th, 2007**

Contaminated sediments in Italy: Methodological approaches and state of the art of characterisation and reclamation activities carried out within Sites of National Interest



C. Mariotti, L. De Propriis, T. Sarlo, P. Renzi, S. Geraldini



ICRAM and SIAP



Istituto Centrale per la Ricerca scientifica e tecnologica Applicata al Mare
(Central Institute for Marine Research)

ICRAM

Provides scientific and technical support to Local and National Authorities, i.e. guidelines, standard procedures, applied research on:

- Monitoring of coastal waters, offshore dumping sites and offshore oil and gas platforms;
- Harbour dredging and beach nourishment;
- Characterization and evaluation of marine polluted areas;
- Experimental sediment clean up or remediation;
- Fisheries and aquaculture;
- Marine Protected Areas and biodiversity conservation



SI Sviluppo Italia
Aree Produttive

Provides technical support and operative activities to Ministry of Environment and Regional Authorities on:

- Characterization and evaluation of polluted sites of National Interest;
- Planning and design of Emergency and Safety measures and Remediation projects;
- Preparation of technical specifications;
- Public tenders for characterization and remediation of polluted sites;
- Supervising and Job Management of field site works



ICRAM and SIAP are respectively the technical-scientific and the working structure that carry out characterization and remediation plans for National Interest contaminated sites.

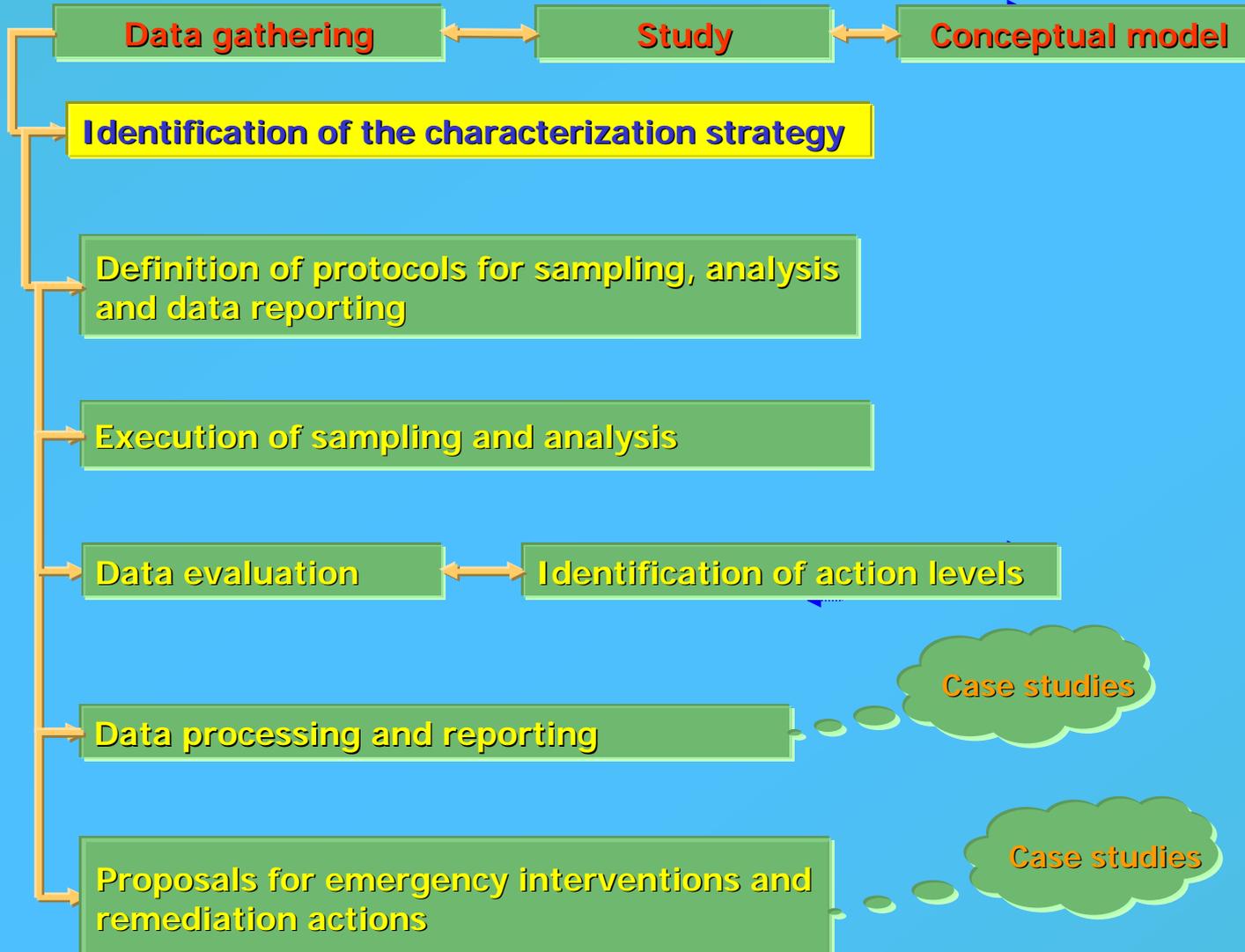


Contaminated Sites of National Relevance concerning sea areas





PROCESS METHODOLOGY





CHARACTERIZATION GOALS

- Determination of the horizontal and vertical distribution of contaminants in sediments
- Determination of possible correlations between sediment pollutants distribution and sediment grain size characteristics
- Evaluation of the effects of contamination to marine organisms and identification of pollutants bioavailability and potential transfer to the food chain
- Determination of the concentration of contaminants along the water column (in particular cases and sensitive areas)
- Determination of the natural contribution to heavy metals and trace elements concentration (geochemical anomalies)



- Identification of more critical areas
- Identification of technical elements and criteria for the definition of safety actions and remediation interventions



CHARACTERIZATION ACTIVITIES

- Gathering of all available information on the areas of interest with respect to:
 - surrounding environment
 - soil, surface water and ground water contamination
 - marine areas, with particular care to legitimate uses and sanitary risks
- Execution of geophysical investigation surveys for bottom morphology and bottom stratigraphy
- Execution of surveys to identify remaining submerged war weapons
- Execution of sediment sampling for physical, chemical and microbiological analyses
- Execution of ecotoxicological analyses on sediments
- Execution of bioaccumulation tests on selected marine organisms
- Eventual sampling and analysis along the water column



SEDIMENT SAMPLING STRATEGY (SEA BOTTOM AND BEACHES)

SITE TYPOLOGY

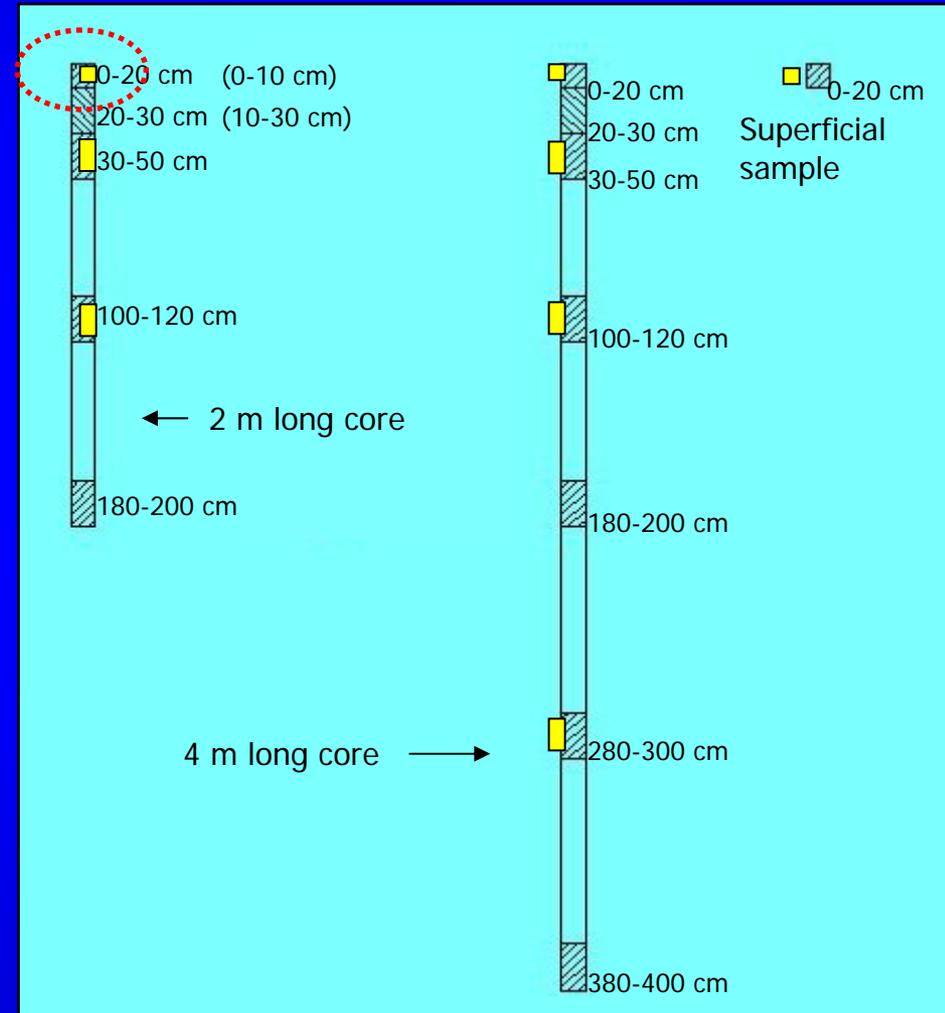
- Coastal area located directly in front or sideway of the upland contaminated site
- “Partially closed” or enclosed port area
- Lagoon

CHARACTERIZATION STRATEGY

- **On bottom sediments:**
 - regular grid (from 450x450 m to 150x150 m, up to 50x50 m)
one sampling station per grid (cores)
 - transects perpendicular to the coast at fixed distance
from 3 to 5 sampling stations along each transect (superficial samples and/or cores)
- **On beaches**
 - transects perpendicular to the coast at fixed distance
from 1 to 3 sampling stations along each transect (cores)
 - regular grid (up to about 50x50 m)
one sampling station per grid (cores)

SAMPLE SELECTION FOR THE EXECUTION OF PHYSICAL, CHEMICAL AND MICROBIOLOGICAL ANALYSES

- Cores of length ≥ 2 m and diameter ≥ 10 cm by means of vibrocores
- Sampling of specific sections along the sediment core
- In ports and lagoons sampling of the superficial 0-20 cm section instead of the 0-10 cm and 10-30 cm sections
- Sampling with grab or box-corer for a section representative of the superficial layer
- Execution of the analyses on a limited number of sections
- Execution of some "continuous" cores, with analyses of some elements on small consecutive sections, in order to find out the contamination trend in time, the contributions of local natural geochemical characteristics, and the reference concentration values in the area





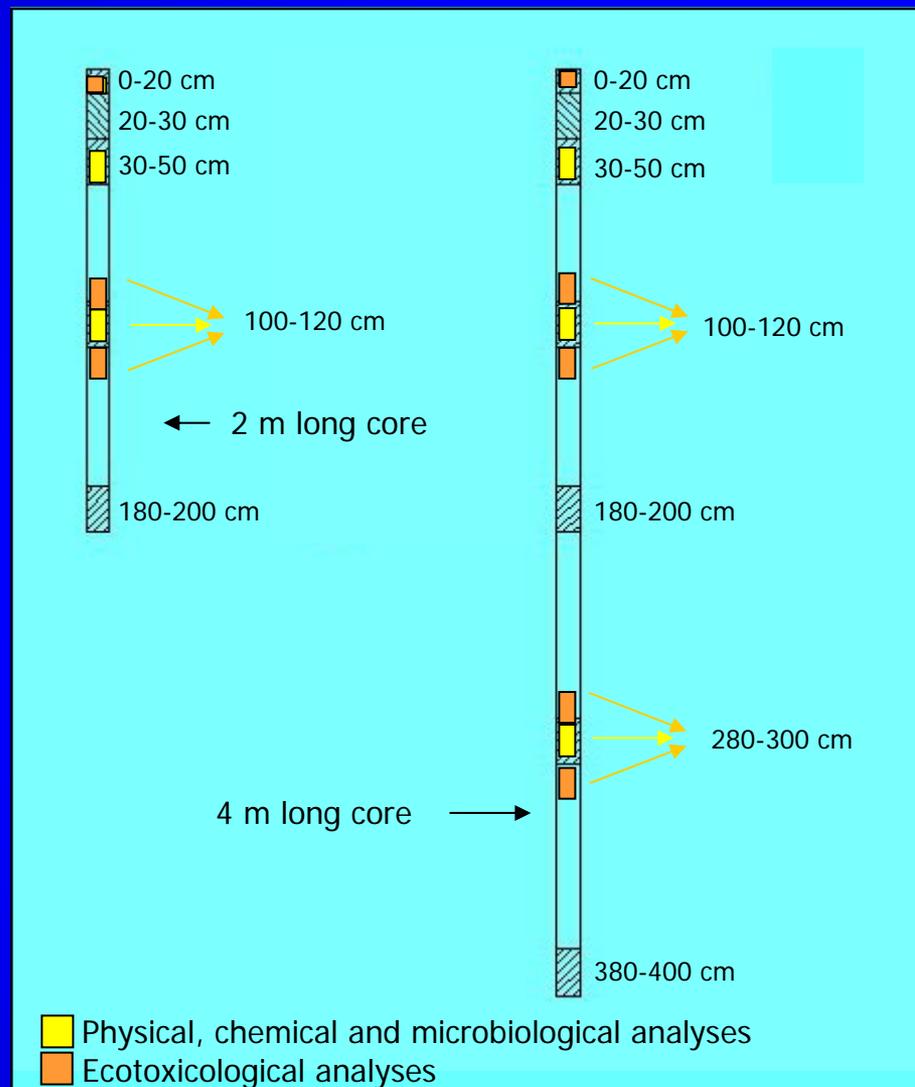
SAMPLE SELECTION FOR THE EXECUTION OF ECOTOXICOLOGICAL ANALYSES

• Superficial sample

Sampled at the same location with grab or box-corer, for a thickness similar to the superficial section of the core (selected for the chemical analyses)

• Deep sample

Obtained mixing the right upper and the lower sediment layer of the section selected along the core for the chemical analyses





PHYSICAL, CHEMICAL & MICROBIOLOGICAL ANALYSES TO BE EXECUTED ON SEDIMENTS

GENERAL PARAMETERS (to be investigated on all samples)

- pH, redox potential
- Grain size, water content
- Concentration of:
 - Metals and trace elements (Al, As, Cd, Cr, Hg, Ni, Pb, Cu, Zn, V)
 - PCBs
 - Chlorinated pesticides
 - PAHs
 - Hydrocarbons ($\leq C_{12}$, $> C_{12}$)
 - Total nitrogen and phosphorous
 - Cyanide
 - Total Organic Carbon

SITE SPECIFIC PARAMETERS

(to be investigated on a reduced number of selected sections)

Concentration of:

- Chloroaromatics
- Phenols
- Aromatic solvents (BTEX)
- Organotin compounds (TBTs)
-
- Asbest
- Dioxins

MICROBIOLOGICAL ANALYSES

(to be investigated on a limited number of selected sections)

- Faecal Streptococci, Salmonellas, Spores of sulphite-reducing clostridiums, *Eschericia coli*, Mycetes



ECOTOXICOLOGICAL ANALYSES TO BE EXECUTED ON SEDIMENTS

To be executed on a reduced percentage of selected sediment samples:

➤ on two matrices:

- Centrifuged sediment or whole sediment
or:
- Pore water or elutriate

➤ by means of a battery of bioassays containing at least two of the following species, selected on specific and recognized protocols:

- *Vibrio fischeri* (Bacteria)
- *Dunaliella tertiolecta* (Chlorophyceae)
- *Brachionus plicatilis* (Rotifera)
- *Corophium* spp (Amphipoda)
- *Paracentrotus lividus* (Echinoida)
- *Dicentrarchus labrax* (Moronidae)



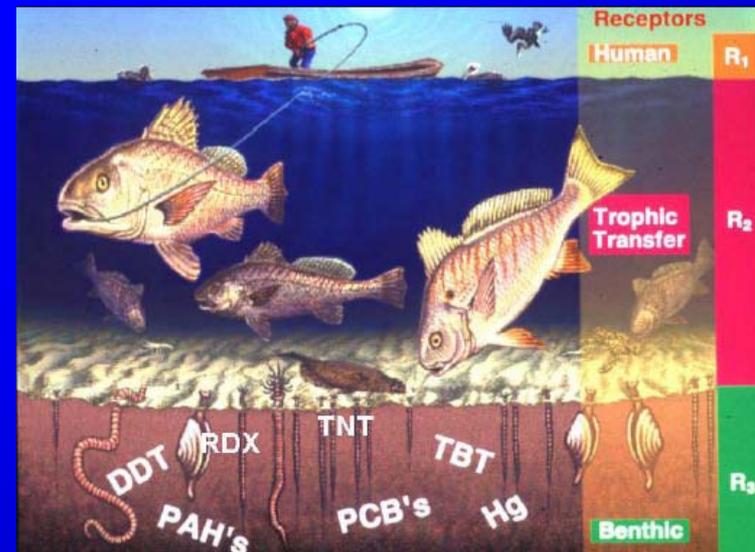
BIOACCUMULATION TESTS ON SPECIFIC ORGANISMS

Marine organisms with proper characteristics:

- filter-feeding organisms such as, for example, clams (*Mytilus g alloprovincialis*)
- necto-benthic species, selected among those who live closer to the bottom, such as, for example: *Mullus barbatus*, *Salpa* spp, *Serranus cabrilla*, *Mugil* spp

Selected chemical analyses:

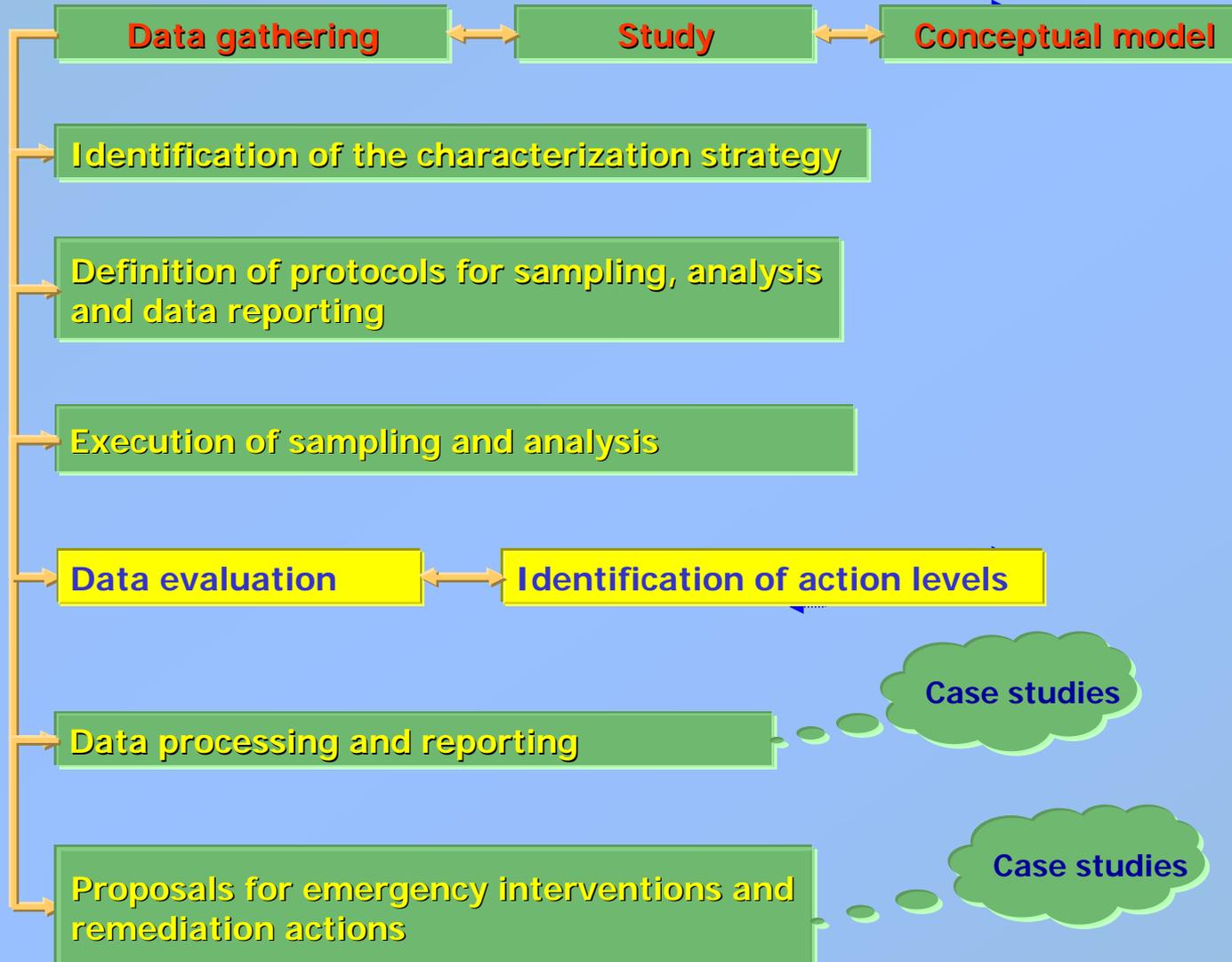
- heavy metals and trace elements
- PAHs
- PCBs
- Specific parameters



(USACE, 2002)



PROCESS METHODOLOGY





SEDIMENT QUALITY EVALUATION: THE ACTION LEVELS

In line with the EC Directive 2000/60/CE for specific water bodies

On the basis of chemical and ecotoxicological criteria and taking into account the local geochemical characteristics, ICRAM has found out, for marine and lagoon sediments, within some of the contaminated sites of national interest:

- **"action levels"**: for sediments of coastal and marine water bodies, highly modified due to past or present human activities (port areas, industrial areas, etc.), in order to evaluate the sediment contamination level and the correspondent potential danger for the aquatic environment, allowing the identification of the areas where intervention actions are urgently needed
- **"reference values"** : for sediments of coastal and marine water bodies, to have reference concentration levels compatible with all legitimate uses (aquaculture, bathing, etc.)

SEDIMENT QUALITY

"GREEN" SEDIMENTS
Concentration values lower than the action levels – no remediation intervention is needed

"YELLOW" SEDIMENTS
Concentration values for which further investigation and/or remediation interventions are needed

"ORANGE" SEDIMENTS
Concentration values for which remediation interventions need to be activated

"RED" SEDIMENTS
Concentration values for which remediation interventions need to be realized immediately



SEDIMENT QUALITY EVALUATION: THE ACTION LEVELS

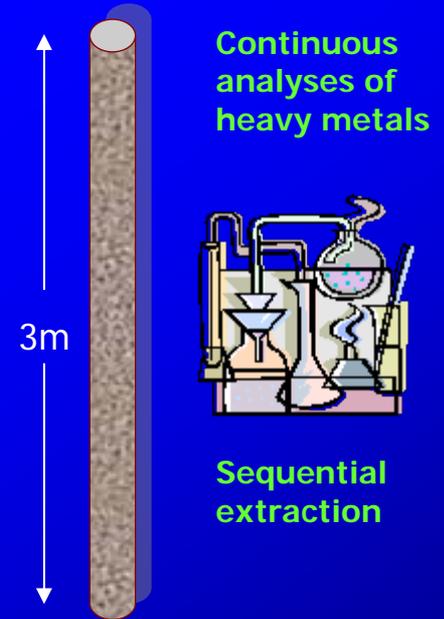
THE (SITE SPECIFIC) ACTION LEVELS ARE BASED ON:

- A. Site specific PEL (*Probable Effect Level*);
- B. International reference values (EPA, CCME, etc.)
- C. Local geochemical and mineralogical characteristics
- D. Toxicity, ecotoxicity, persistence, contaminants bioaccumulation tendency
- E. Specific bibliography
- F. **Specific additional investigations, executed together with or after the site characterization process**

BIOASSAYS



BIOACCUMULATION TESTS





APPLICABILITY OF ACTION LEVELS

THE INTERVENTION PROCEDURE IS ACTIVATED DEPENDING ON:

- How much the parameters are above the action levels
- Which parameter is above the action levels
- Volumes and spatial distribution of sediments with concentrations higher than the action levels
- Use of the area

The intervention procedure is activated in the following cases:

- More than 10% of the samples has concentration values higher than the action levels;
- One or more parameters have concentration values higher than the following thresholds:
 - 110% of the action levels for Cd, Hg, Organotin compounds, Dioxins, PCBs
 - 150% of the action levels for Cu, Zn
 - 100% of the action level for PAHs
 - 120% of the action levels for all remaining parameters

The intervention procedure is not activated in the following cases:

- All parameters have concentration values lower or equal to the action levels
- Less than 10% (or 10%) of the samples has concentration values higher than the action levels and the above thresholds are never crossed



APPLIED RESEARCH FOR THE IDENTIFICATION OF INTERVENTION ACTIONS



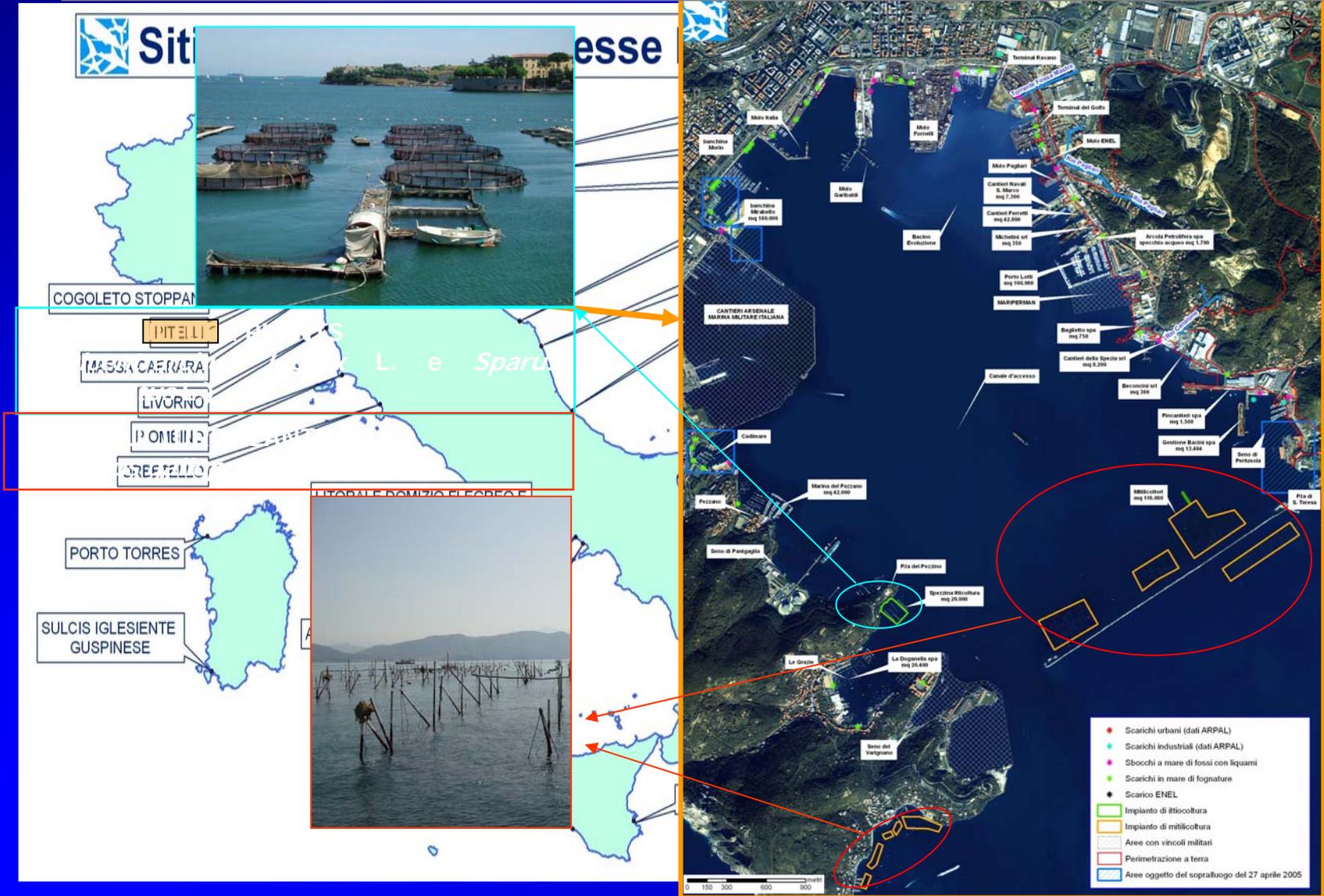


PROCESS METHODOLOGY

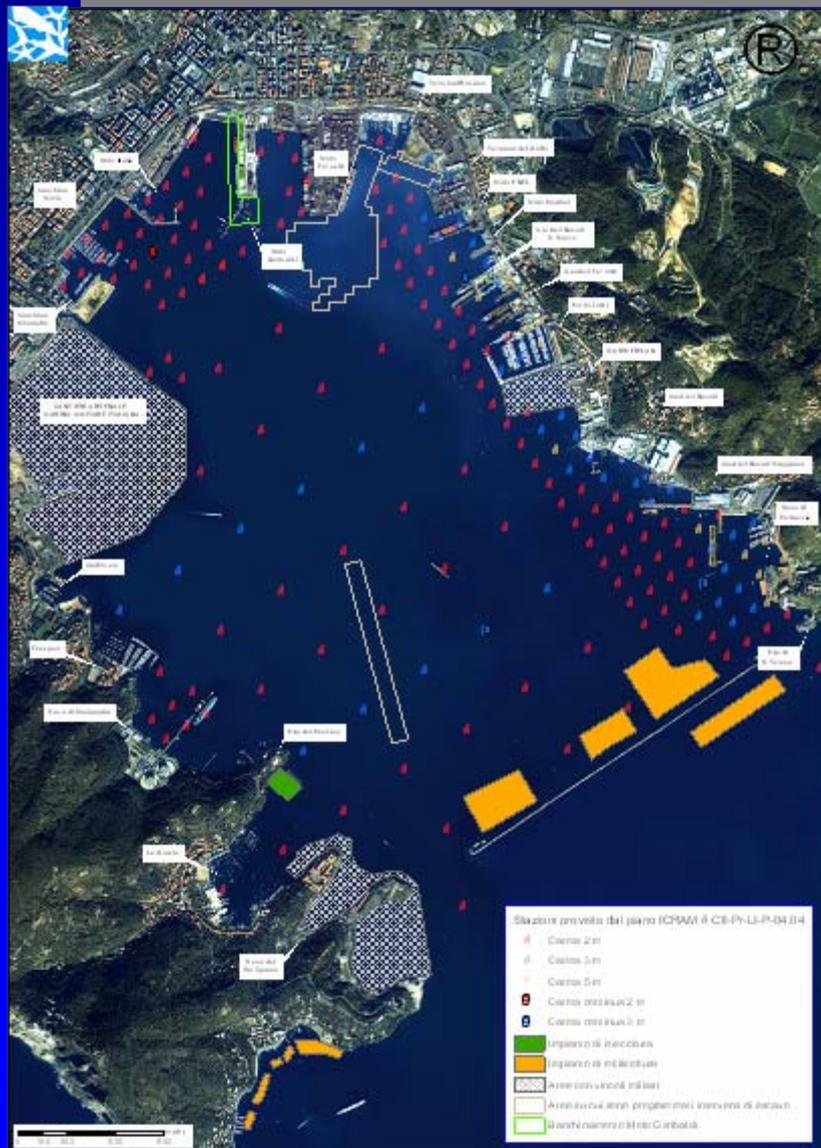




CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PITELLI (GULF OF LA SPEZIA)



CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PITELLI (GULF OF LA SPEZIA)



189 CORES SAMPLED

759 SAMPLES ANALYSED

ANALYSES:

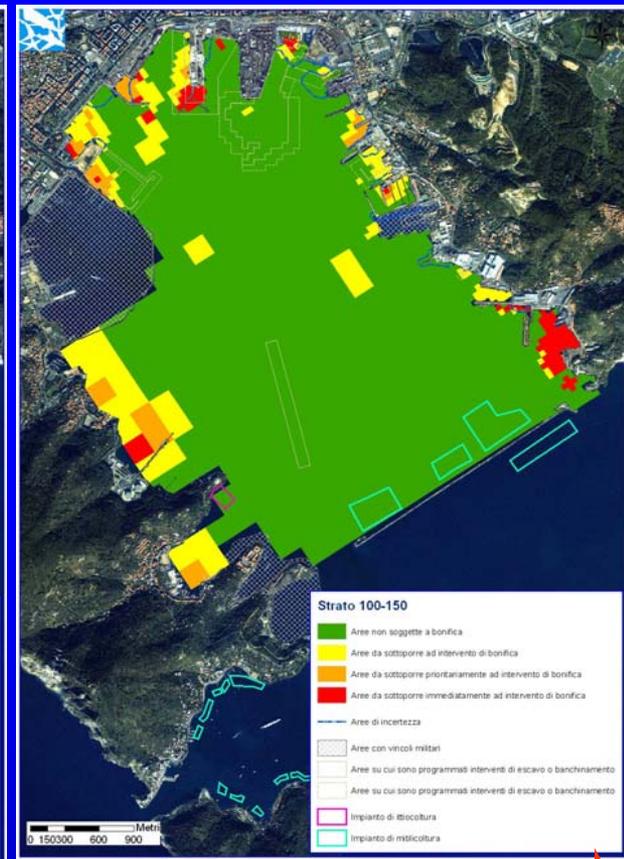
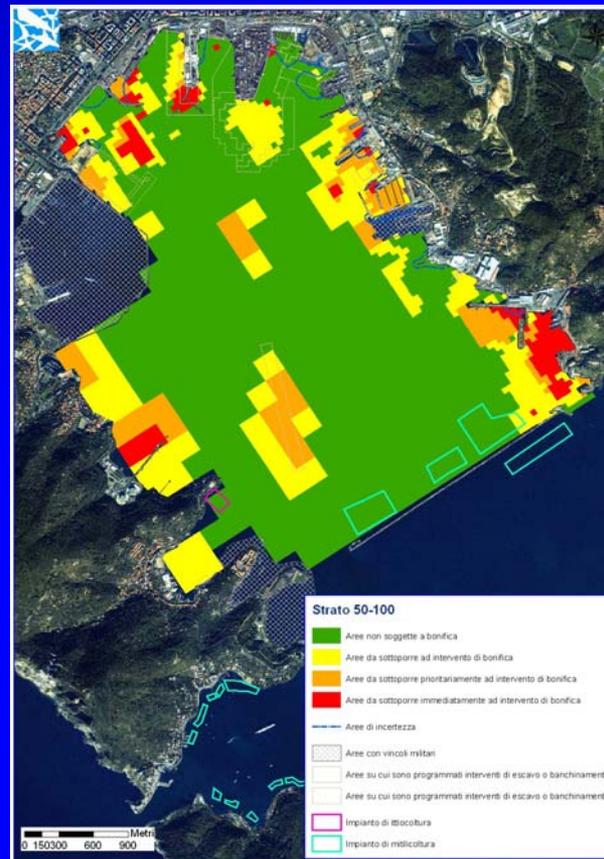
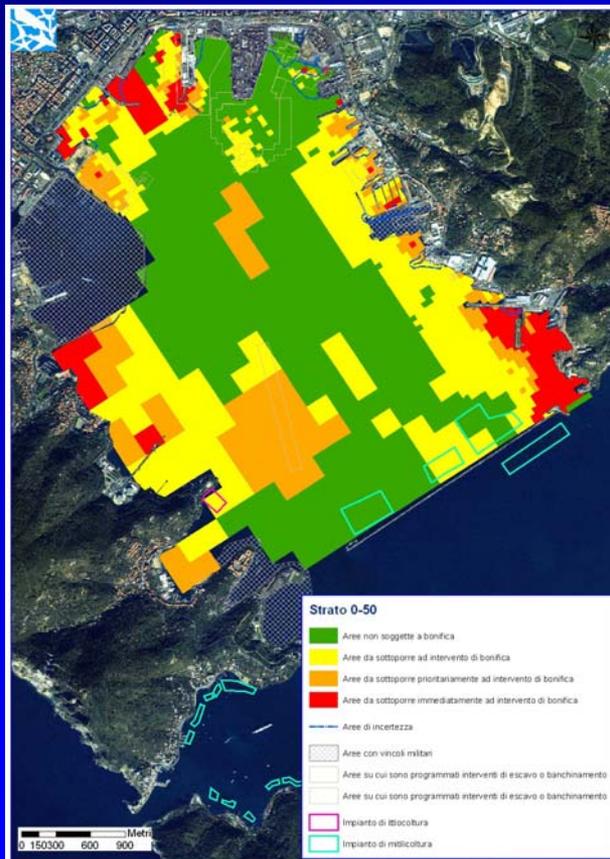
- on 759 samples: pH, redox potential, grain size, heavy metals and trace elements, PAHs, PCBs, N, P, TOC, Cyanide, Hydrocarbons C>12 and C<=12
- on 220 samples: microbiological analyses
- on 160 samples: organotin compounds
- on about 80 samples: Sn, Co, chlorobenzene, chlorofenols, aromatic solvents
- on about 20 samples: dioxins and furans, asbest
- on 15 samples: ecotoxicological analyses

Executed by:

- ARPAL (n.105 cores), on request of Region Liguria
- Sviluppo Italia Aree Produttive S.p.A. (n. 65 cores), on request of Region Liguria
- La Spezia Port Authority (n.19 cores)



CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PITELLI (GULF OF LA SPEZIA)



SEDIMENT QUALITY

“GREEN” SEDIMENTS
Concentration values lower than the action levels – no remediation intervention is needed

“YELLOW” SEDIMENTS
Concentration values for which further investigation and/or remediation interventions are needed

“ORANGE” SEDIMENTS
Concentration values for which remediation interventions need to be activated

“RED” SEDIMENTS
Concentration values for which remediation interventions need to be realized immediately



**CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PITELLI (GULF OF LA SPEZIA):
VOLUMES OF SEDIMENT THAT NEEDS REMEDIATION**

LAYER [cm]	SEDIMENT VOLUME "YELLOW" [m ³]	SEDIMENT VOLUME "ORANGE" [m ³]	SEDIMENT VOLUME "RED" [m ³]	TOTAL VOLUME per layer [m ³]
0-50	1.770.600	855.150	458.550	3.084.300
50-100	1.123.050	452.350	253.700	1.829.100
100-150	571.900	139.800	140.700	852.400
150-200	272.700	93.900	29.300	395.900
200-250	186.150	49.250	6.100	241.500
250-300	126.600	59.450	4.250	190.300
TOTAL up to 3 m	4.051.000	1.649.900	892.600	6.593.500



PRELIMINARY REMEDIATION PROJECT: POSSIBLE MANAGEMENT OPTIONS

“RED” SEDIMENTS

- Disposal in an upland waste site
- (Ex situ) treatment for later disposal in CDF or coastal confined structures

“ORANGE” SEDIMENTS

- Dredging and disposal in CDF or coastal confined structures
- Dredging and (ex situ) treatment for later reuse in civil works, according to the existing legislation

“YELLOW” SEDIMENTS

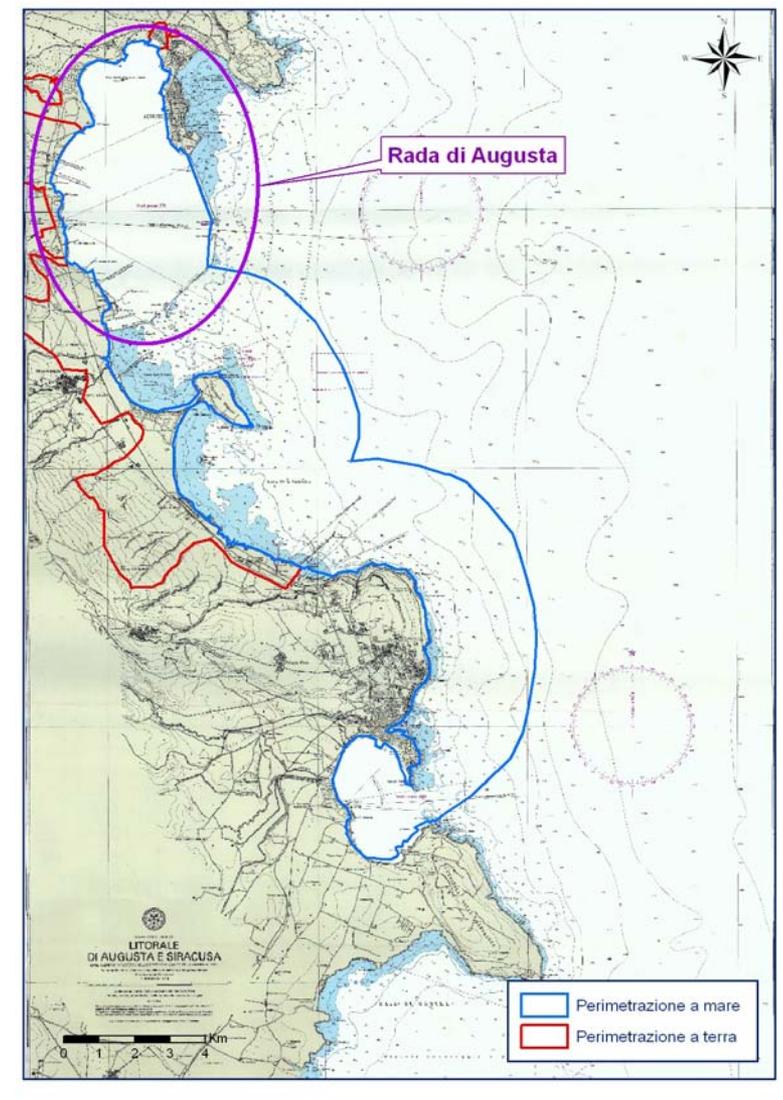
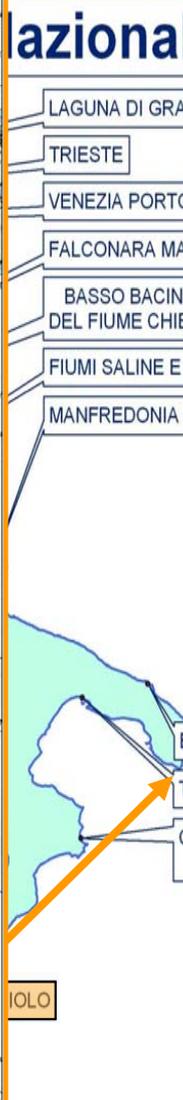
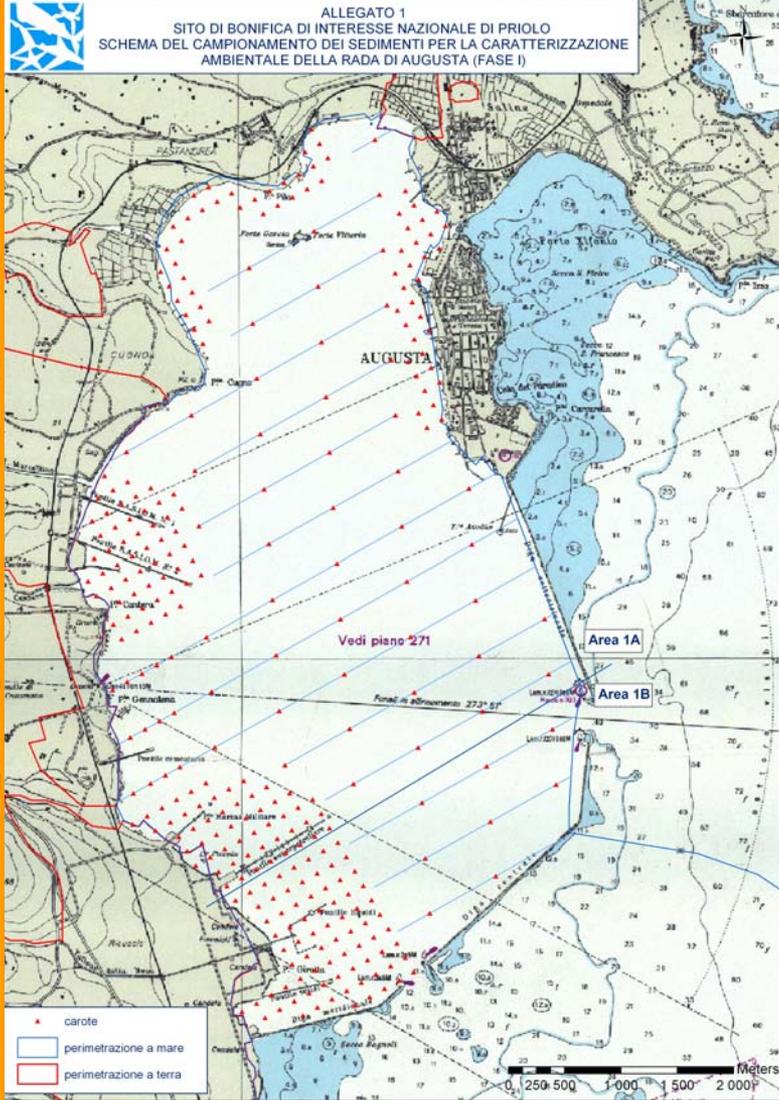
- Additional investigation and monitoring
- In situ treatment
- Dredging and disposal in CDF or coastal confined structures
- Dredging and (ex situ) treatment for later reuse in civil works, according to the existing legislation

AN INTERVENTION HYPOTHESIS MUST:

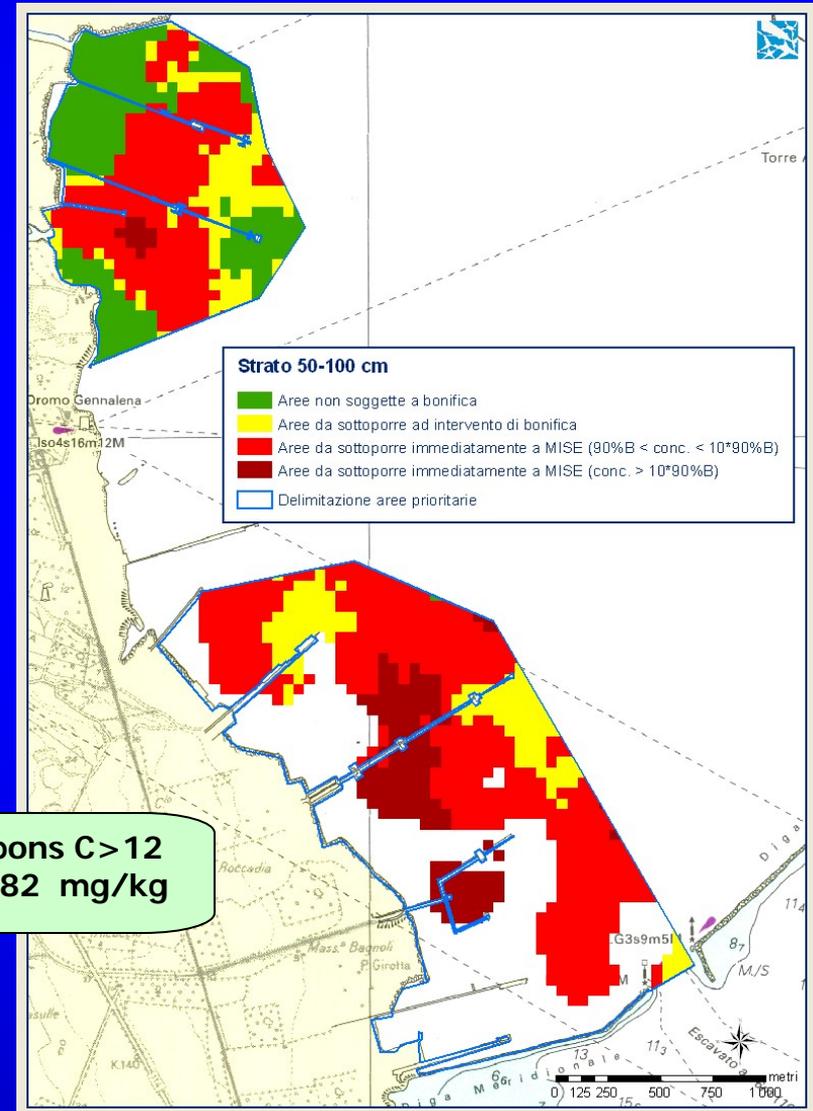
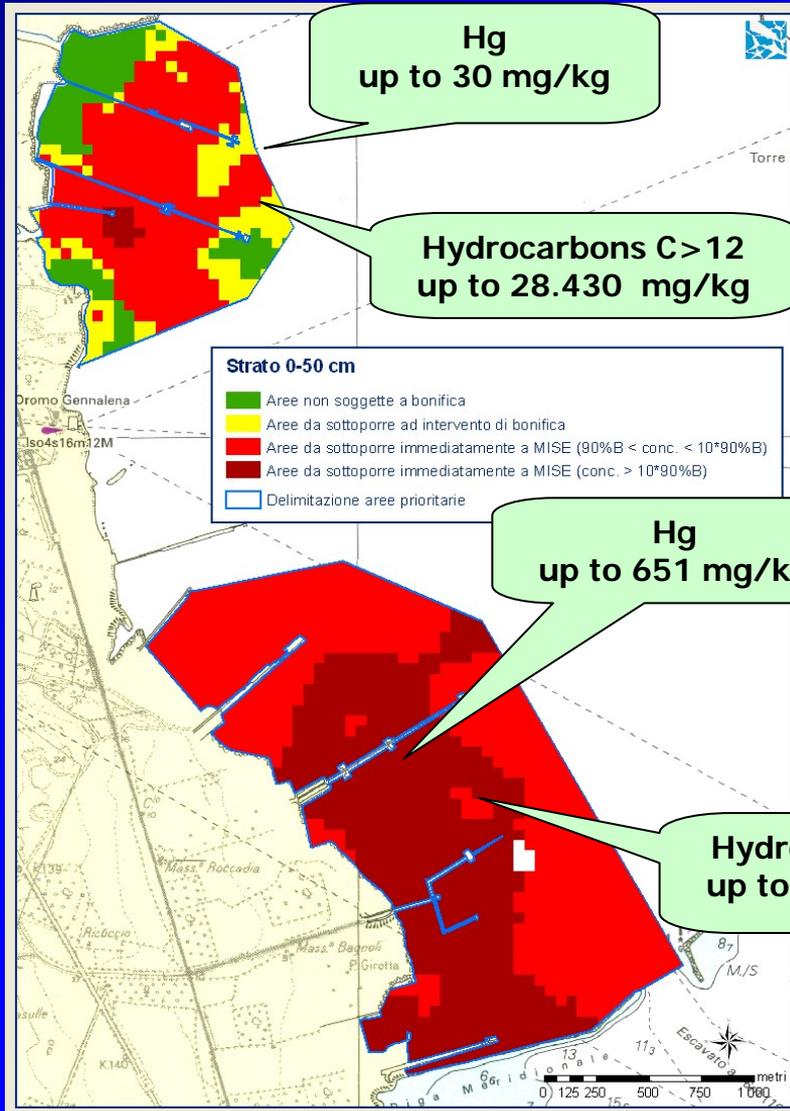
- be formulated in line with human and environmental protection (concentration values, risk for contamination diffusion, use of the area)
- adopt specific mitigating measures
- include a monitoring plan of all intervention phases in order to minimise the impacts and check the effectiveness of the mitigating measures
- include monitoring activities of the “residual” contamination
- foresee eventual limitations of the legitimate uses of a specific area



CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PRIOLO (PORT OF AUGUSTA)

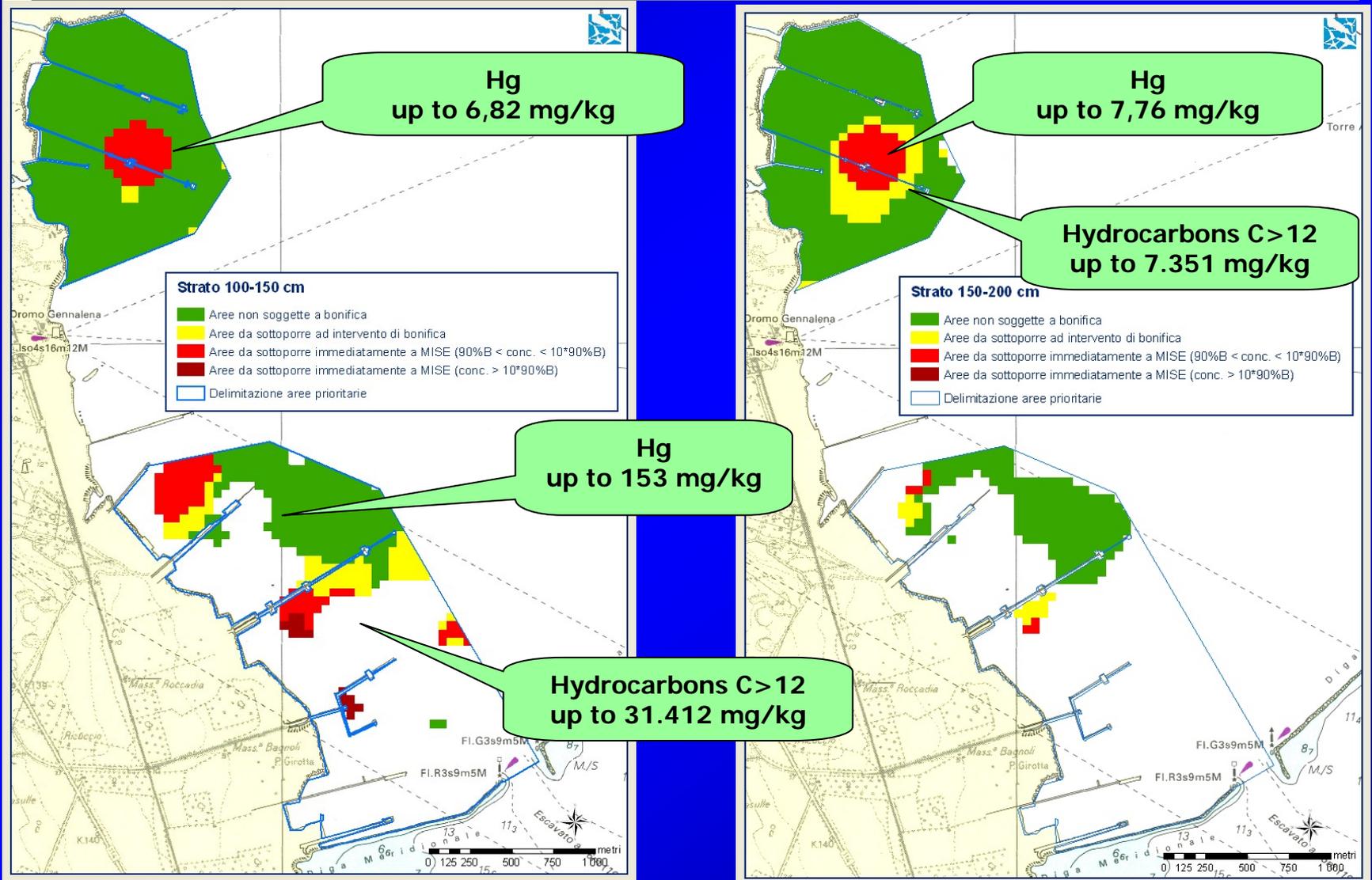


CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PRIOLO (PORT OF AUGUSTA) – 1st phase

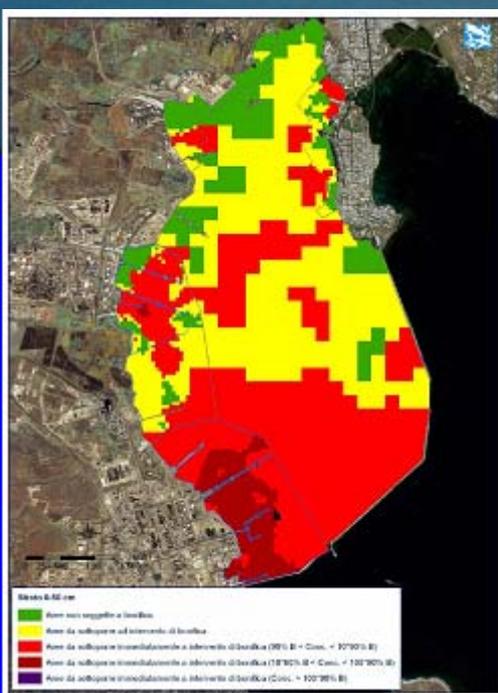




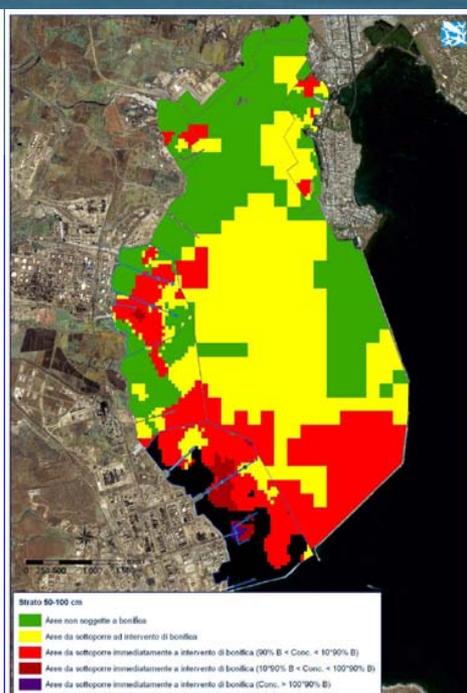
CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PRIOLO (PORT OF AUGUSTA) – 1st phase



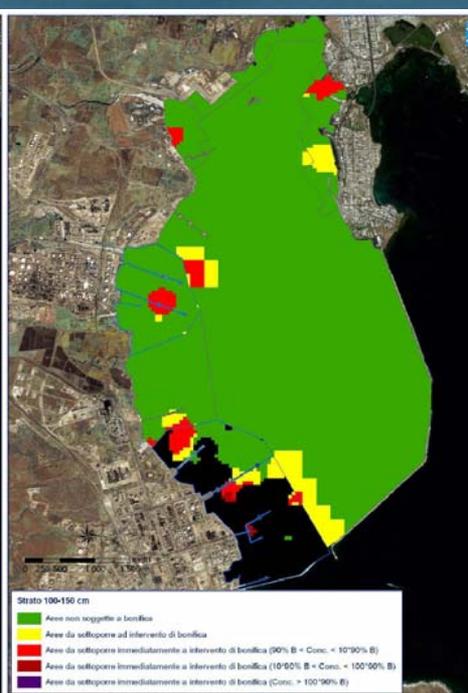
CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST OF PRIOLO (PORT OF AUGUSTA) – 2nd phase



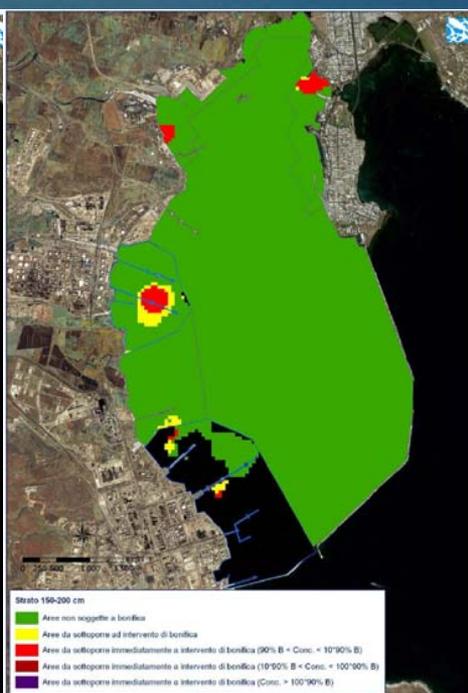
Level 0 – 50 cm



Level 50 – 100 cm



Level 100 – 150 cm



Level 150 – 200 cm

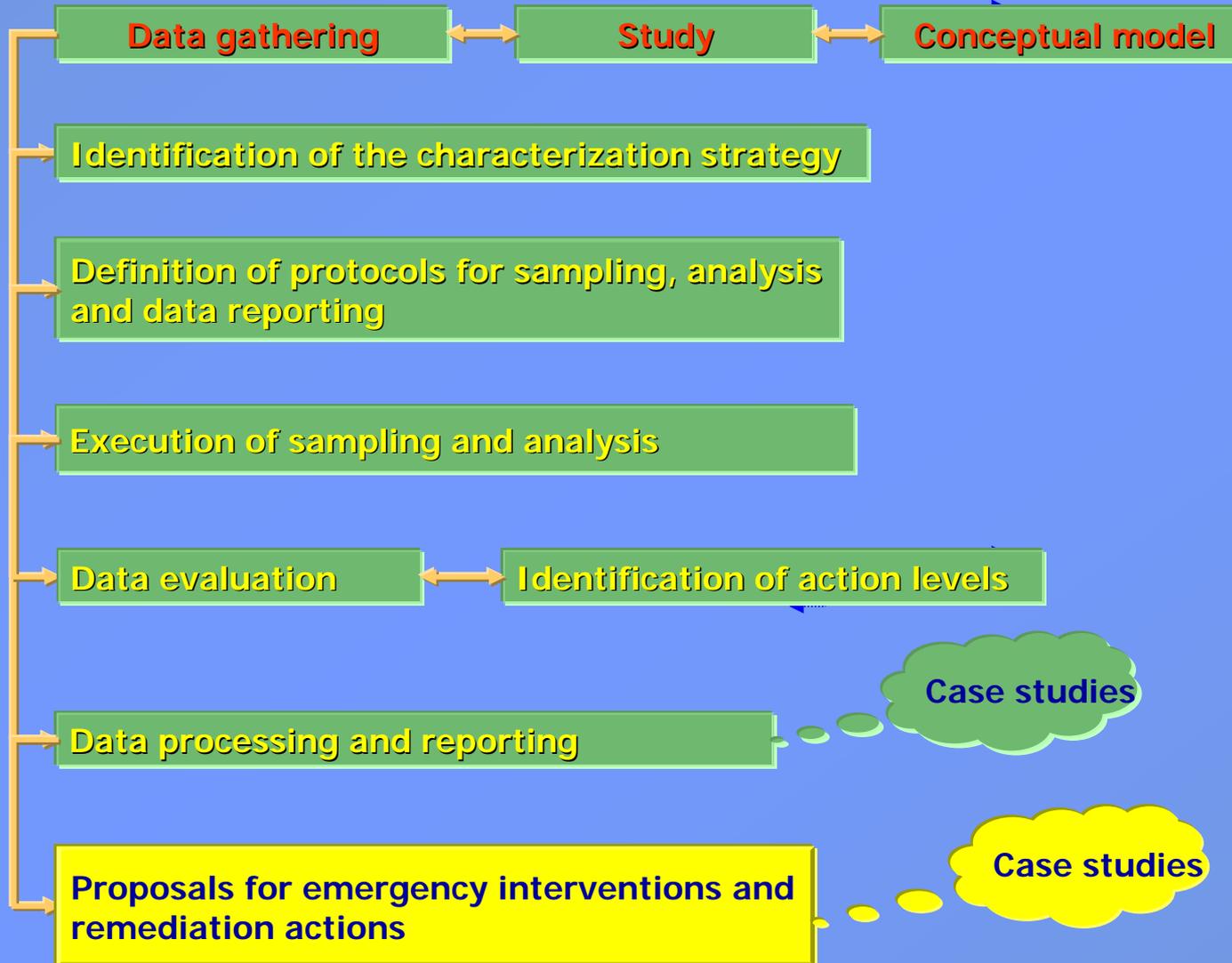


**CHARACTERIZATION RESULTS IN THE CONTAMINATED SITE OF NATIONAL INTEREST
OF PRIOLO (PORT OF AUGUSTA):
VOLUMES OF SEDIMENT THAT NEEDS REMEDIATION**

Layer [cm]	V.I. < Conc. < 90% col. B [m ³]	90% col. B < Conc. < 10x90% col.B D.M. 471/99 [m ³]	10x90% col.B D.M. 471/99 < Conc. < 100x90% col.B D.M. 471/99 [m ³]	Conc. > 100x90% col.B D.M. 471/99 [m ³]
0-50	4.217.046	4.902.490	728.054	0
50-100	4.361.436	2.551.436	153.277	17.382
100-150	508.455	299.980	17.400	0
150-200	122.289	139.020	0	0
Tot	9.209.226	7.892.924	898.731	17.382
			8.809.037	
TOTAL	18.018.263 m³			

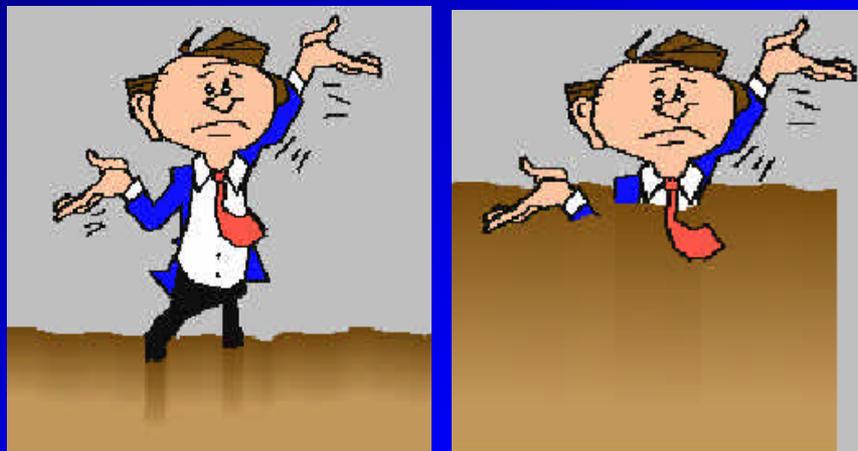


PROCESS METHODOLOGY

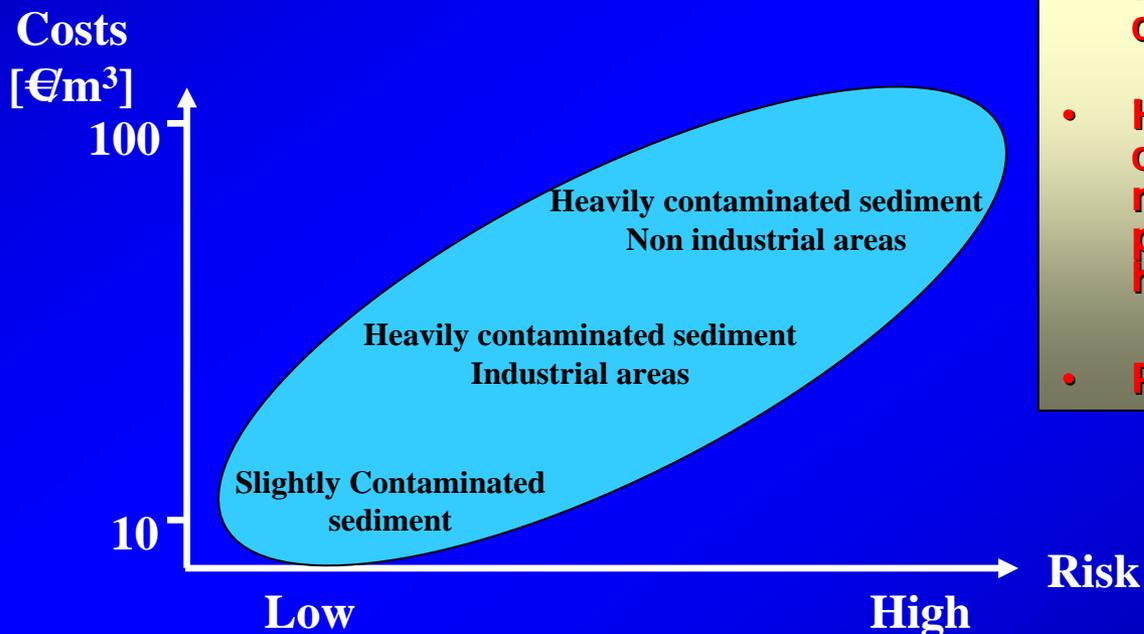




THE PROBLEM



- Presence of large volumes of heavily contaminated sediments, and a high bioavailability of contaminants.
- European Directive about water bodies (2000/60/CE)
- Few known handling options of contaminated sediments
- Huge quantities of contaminated materials that need to be treated before a possible re-use or disposal, with high managing costs
- Poor national legislation





DEFINITION OF INTERVENTION ACTIONS

Characterization

Evaluation

No action

Definition of possible interventions

Additional characterization

Processing

Emergency actions and/or remediation actions

Environmental monitoring

In situ management options

Ex situ management options

- Limited area uses
- Confining
- Monitoring
- In situ treatment:
 - Biofarming
 - Phytoremediation
 - Capping

Environmental dredging

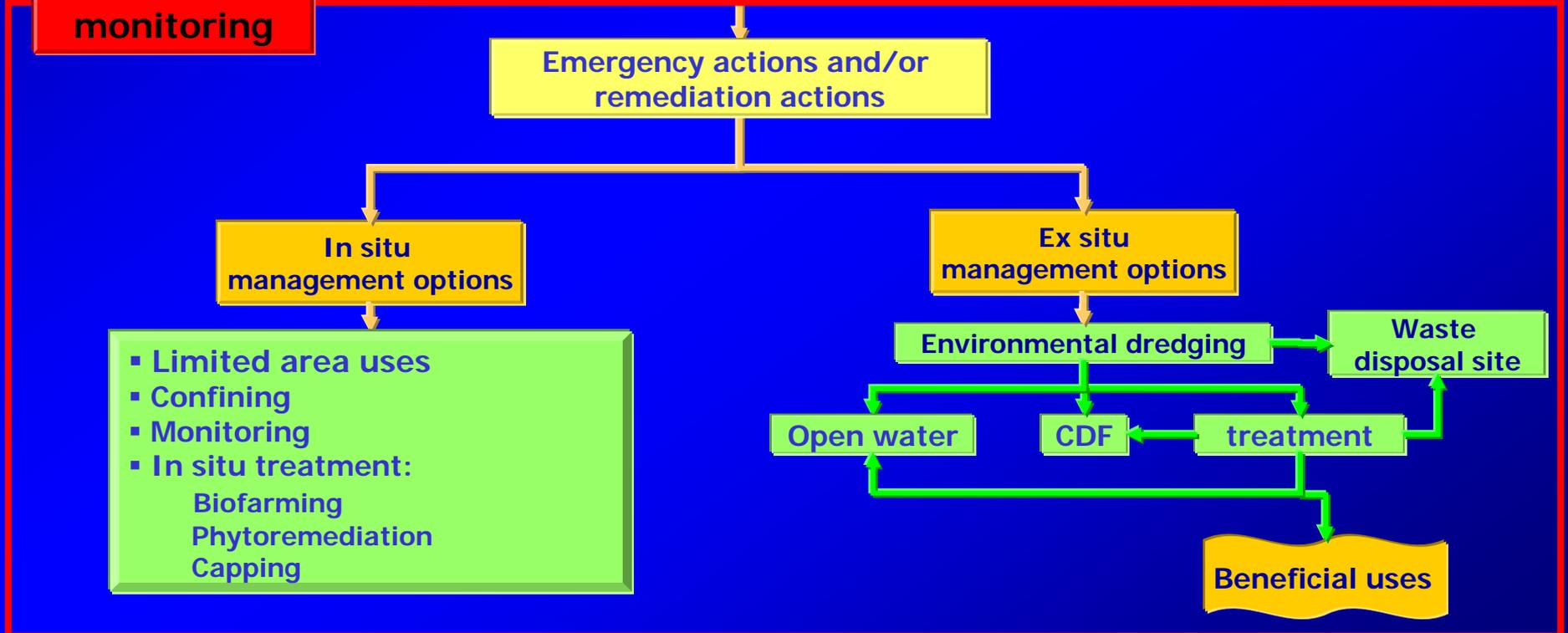
Waste disposal site

Open water

CDF

treatment

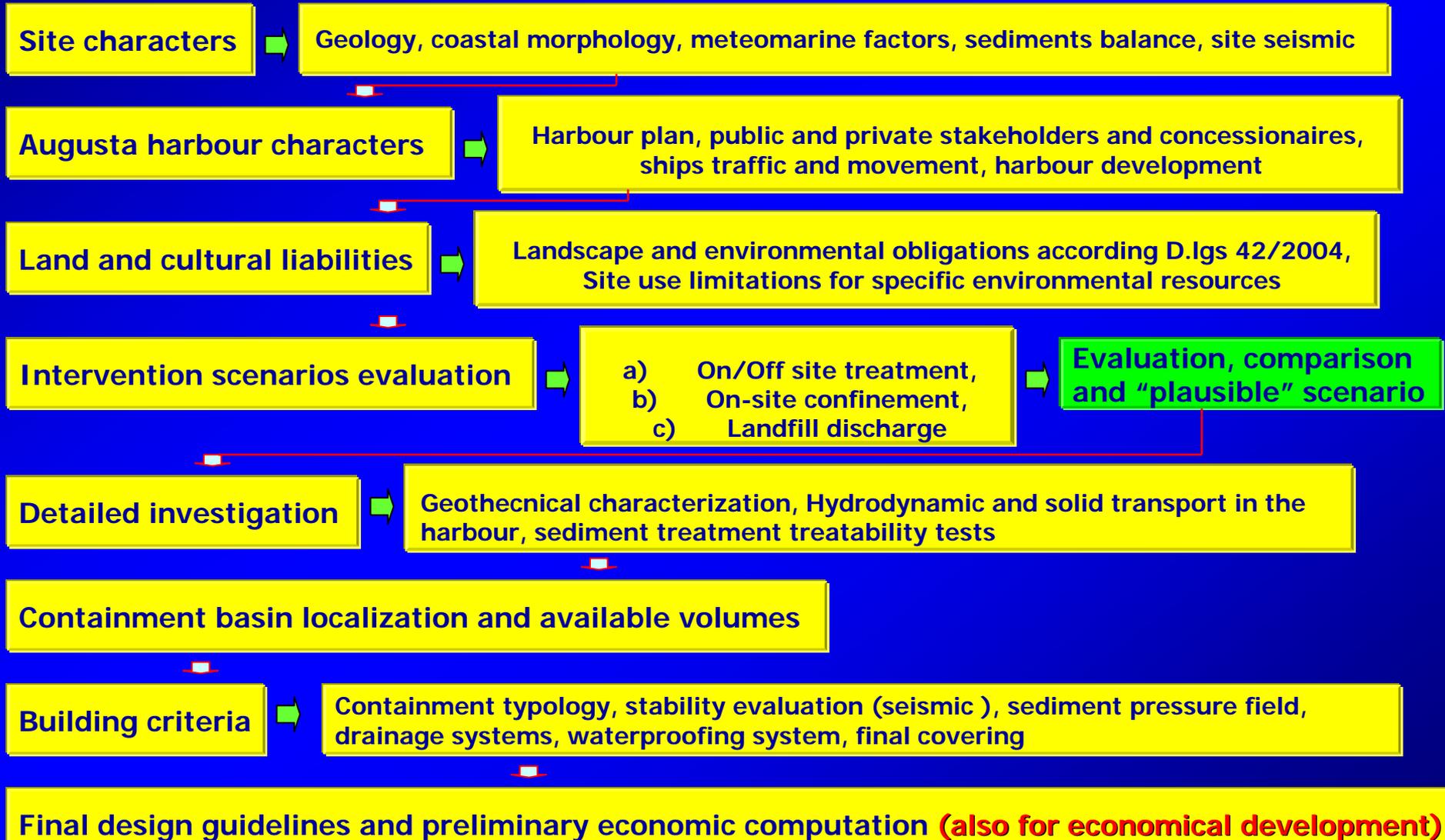
Beneficial uses





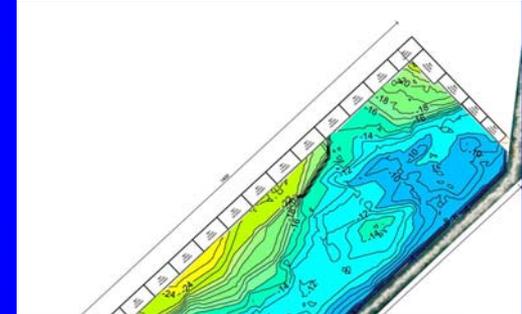
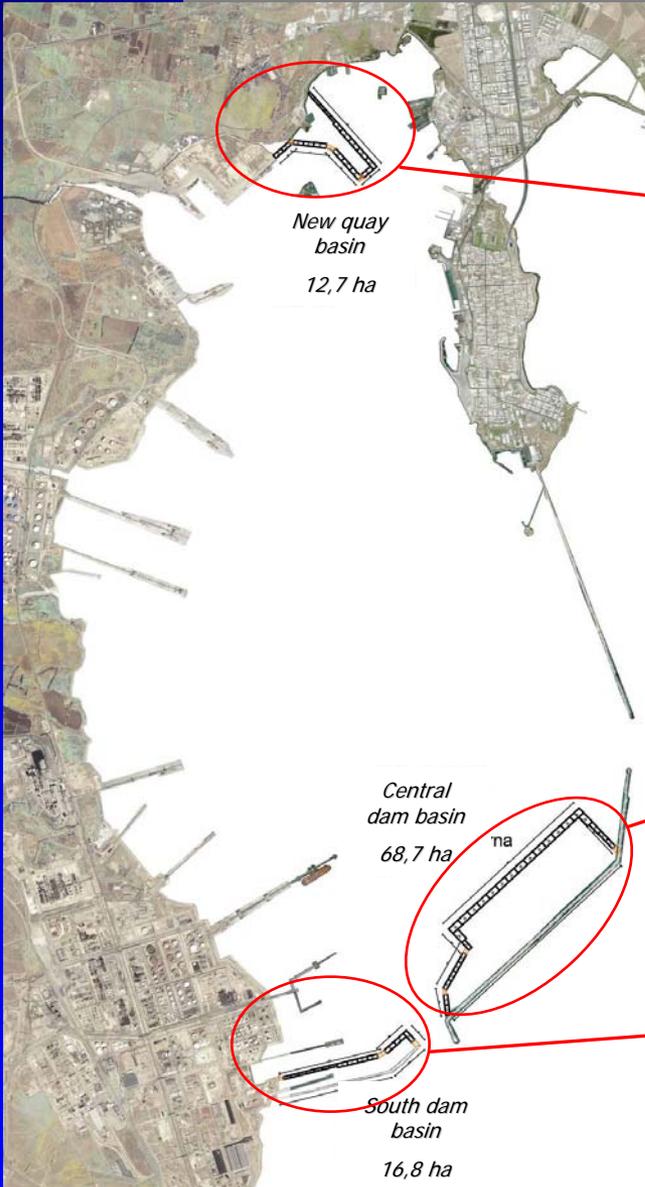
INTERVENTION ACTION FOR PRIOLO SITE (PORT OF AUGUSTA)

SITE APPROACH (according site characterization)





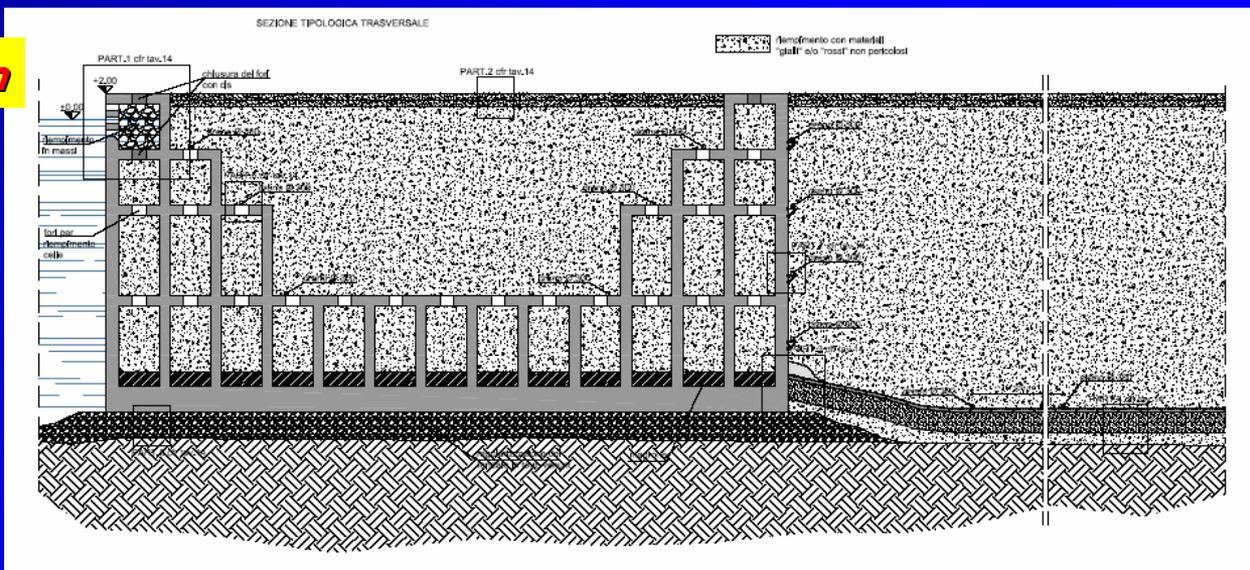
INTERVENTION ACTION FOR PRIOLO SITE (PORT OF AUGUSTA)



INTERVENTION ACTION FOR PRIOLO SITE (PORT OF AUGUSTA)

Main characters of containment basins

Type section



Available volume

BASIN	Available volume from preliminary dredging	Constructed basin volume	Reduced volume from bottom capping	Concrete cells available volume	TOTAL (m3)
New quay basin	40.840,00	1.014.445,00	- 452.660,09	688.759,09	1.291.420,09
Central dam basin	821.412,00	9.697.683,00	- 2.284.880,00	1.663.265,90	9.897.480,90
South dam basin	212.422,00	1.175.835,00	- 513.240,00	367.647,46	1.242.664,46
	1.074.674,00	11.887.963,00	- 3.250.780,00	2.719.708,45	12.431.565,45



CONCLUSION AND FINAL CONSIDERATIONS

Tens and tens of “wild” discharges from industrial sites posed serious pollution problems on sediments of marine areas, directly raising health disease (up to carcinogenic and mutagenic effects!).

Over hundred of Million m³ of polluted sediments presently lie in 25 National Interest Sites, involving huge technical and economical problems.

There is a need of a systematic approach and common choices, in order to reduce the economic impact of the problem according “human health safeguard” principles.

A possible solution could be a “marriage” between environmental/health items and economical development (or re-development) of sites where pollution occurred, to transform a “free-grant burden” in a territorial opportunity.