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RATIONAL APPROACH TO THE SOLUTION OF THE PROBLEM OF WASTEWATERS MANAGEMENT-THE KAŠTELA BAY CASE

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ABSTRACT
Uncontrolled disposal of urban and industrial wastewaters into the sea led to the fact that in mid eighties the Kaštela Bay, near the city of Split, Republic of Croatia, became one of the largest and most widely known pollution "hot-spot" areas of the Mediterranean region. The pollution of the Bay caused "red tide" and mass mortality of marine organisms. Numerous conflicts arose, and the quality of life was reduced due to the changed quality of the sea. Local communities recognized the problem, and the long-term solution of wastewater management has been developed. This solution envisages the collection of all domestic wastewaters at two points in the area, and, after treatment at an appropriate level, their discharge via long submarine outfalls into a less sensitive marine environment. For the implementation of the first phase of the long-term solution, a project "Eco Kaštela Bay" has been launched. The project is financed from local and governmental sources, as well as loans of the World Bank and the European Bank for Reconstruction and Development. The present paper describes the area, environmental conditions, and the approach applied in the long-term solution of waste waters management.

KEYWORDS: sewage; sewerage system; marine disposal; ecological approach; Kaštela Bay.

INTRODUCTION

Most of the world population lives in coastal areas, particularly in large coastal cities, which have been quickly growing over the past several decades (Olsen, 1993). It is assumed that in the future the coastal area will be exposed to an even greater population pressure, development and changes in national economies (UN, 1992). The widespread coastal population growth, the extension of urban wastewater discharge networks and the higher standard of living have considerably increased the amount of sewage discharged into the sea. The situation has been aggravated by the continuously growing tourist population and the

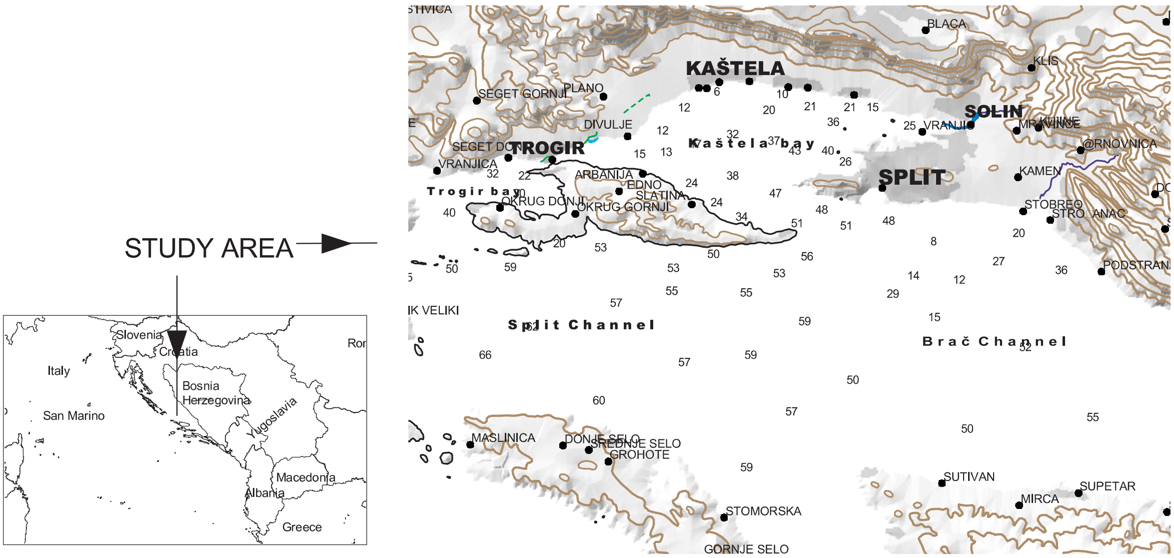

Figure 1. The study area

production of peak quantities of domestic wastes. Population increase and a higher standard of living in the coastal zones, as expected, have been accompanied by the extension and diversification of industries. More new substances have been introduced in industrial processes and products, and new uses found for the existing materials. Most of these changes are reflected in the industrial wastes, and represent an additional dimension of the problem of pollution of the receiving marine environment.

Serious concern about the state of pollution of the coastal sea and negative impacts on both ecosystems and human society, mainly as a result of waste discharges originated from sources located on land (UNEP/WHO, 1996a), led to a general attitude that the marine environment should be protected from land based activities and sources of pollution (UNEP, 1995). For this purpose various criteria and guidelines have been prepared, such as the *Guidelines for Treatment of Effluent prior to Discharge into the Mediterranean Sea* (UNEP/WHO, 1996b), and *Guidelines for Submarine Outfall Structures for Mediterranean Small and Medium-size Coastal Communities* (UNEP/WHO, 1996c).

DESCRIPTION OF THE STUDY AREA

The wider area of the Kaštela Bay, covering the municipalities of Split, Solin, Kaštela and Trogir, is the largest one on the Croatian coast (Figure 1). It represents an economic and territorial entity with the city of Split as the dominant center. The city of Split is the second largest city of Croatia and the administrative center of the County of Split-Dalmatia.

The total population of the narrow coastal strip, limited by the seashore and mountain slopes, and covering approximately 14,500 hectares, has tripled over the past half a century, with 280,000 inhabitants in the year 1991, while the estimated population for the year 2015 is 355,000. The fast population growth was accompanied by the development of industry, traffic and trade.

The climate of the area is of the Mediterranean type, characterized by dry summers and wet winters. Average annual air temperature is 16 °C. The long-term annual average rainfall is 837.2 mm.

The area of the Kaštela Bay is known as one of the most polluted areas of the eastern coast of the Adriatic. The environmental pollution is a consequence of fast industrialization and urbanization without development of appropriate urban infrastructure, in particular of a wastewater collection and disposal system. Increased amounts of both urban and industrial wastewaters are disposed untreated in the coastal sea resulting in numerous ecological problems and conflicts, as well as in the reduction of quality of living. The main conflicts are between industry and tourism, industry and housing, and waste water discharge and tourism.

Characteristics of the Kaštela Bay and the Brač and Split Channels

Two distinctive water bodies encompass the area of concern: the semi-enclosed Kaštela Bay and the Brač and Split Channels. Despite their interconnection they represent different sea basins in terms of ecological characteristics and impacts from land-based sources.

The Kaštela Bay

The Kaštela Bay is the largest bay of the central part of the Croatian coast. The total surface area of the Bay is 61 km^2 and the average depth is 23 m, resulting in a total volume of 1.4 km^3. The narrow coastal belt of the Bay is densely populated and has a number of various industrial plants.

By its origin the Kaštela Bay is a synclinal fold which was transgraded and submerged in Pleistocene. The Bay displays different bathymetric and morphometric properties, and two separate parts can be clearly distinguished: the deeper eastern and the shallower western ones. The freshwater inflow is, in addition to rainfall, by the numerous submarine springs and small karstic river, Jadro, (yearly average flow is 10 $m^3 s^{-1}$). The fresh water inflow has a strong seasonal fluctuation.

The Bay exchanges the water masses with the adjacent Brač Channel through the entrance between the Marjan peninsula and the island of Ciovo. The water renewal period of the entire Bay is about one month, while of its eastern part it is about 15 days (Zore-Armanda, 1979). Since the volume of the entire Bay is four times greater than the volume of its eastern part, the rate of the water exchange between the eastern part and the rest of the Bay is relatively low. As a result, the eastern part of the Bay is poorly aerated, particularly in the hot period of year.

Vertical temperature distribution indicates the presence of a thermocline in the water column from April to October at a depth of 10-25 m (Buljan and Zore-Armanda, 1996). The fresh water entering into Bay has very limited influence on the salinity variance in the Bay (Zore-Armanda, 1980). The annual mean salinity values in the surface and bottom layer are 34.43 ‰ and 37.27 ‰, respectively.

Based on the primary production, the Kaštela Bay is naturally a moderate productive basin (Pucher-Petkovic and Zore Armanda, 1973.). For the period 1962-1967 the primary production in the Bay was estimated at 150 gC $m^{-2} y^{-1}$. Due to wastes discharge, the primary production in the Bay in the period 1982-1986 increased to 325 gC $m^{-2} y^{-1}$ (Baric *et al.*, 1992). In the summer of 1980 the first "red tide", i. e. an extreme bloom of the dinoflagellate species, *Gonyaulax polyedra*, occurred in the Bay causing mass mortality of marine organisms in the eastern part due to reduced oxygen concentration in the water column (Marasovic and Vukadin, 1982). In the past years the "red tide" has become quite common, not only in the eastern part, but also practically throughout the Bay. Moreover, a significant change in the phytoplankton community structure occurred due to eutrophication (Marasovic and Pucher-Petkovic, 1991). A typical diatom type has gradually been transformed into a community of dinoflagellates. An increase of dinoflagellate proportion is accompanied by a respective increase of primary production. Moreover, new species, such as *Alexandrium minutum* have been introduced. Research over the last thirty years indicated that the structure of the benthic flora of the Bay has changed. Of particular interest is the introduction of new species known as nitrophilic species (Span and Antolic, 1997). Their introduction is favoured by the eutrophic conditions.

Eutrophication in the Kaštela Bay is considerable (Baric *et al.*, 1992). The present nutrient concentrations are in the range as follows: nitrate 0.2-1.0 mmol m^{-3}; nitrate 0.0-0.8 mmol m^{-3}; ammonia 0.5-1.3 mol m^{-3}; phosphate 0.09-0.20 mmol m^{-3}; silicate 0.1-4.0 mmol m^{-3}. The ratio of nitrogen to phosphorous concentrations in the Bay has been reduced to the value of 23, indicating phosphorous introduction by the wastewater having N/P ratio of 6 (Baric *et al.*, 1992). The concentration of dissolved oxygen has increased in the euphotic layer (annual average 5.8 ml dm^{-3}) and decreased in the bottom layer (annual average 5.1 ml dm^{-3}) (Baric *et al.*, 1992). Such a divergent behavior of two layers with respect to dissolved oxygen concentrations indicates a long-term trend of intensified phytoplankton photosynthetic activity in the euphotic layer, followed by an increase in the mineralization of organic matter in the bottom layers. Long-term transparency measurements by the Sechi disc confirm the increase of eutrophication in the Bay with strong negative impacts on the ecosystem.

The Bay is contaminated by heavy metals, particularly mercury. Mercury was released into the Bay from a chlor-alkaly plant for about 40 years, until 1990. The estimated total amount of mercury discharged into the Bay is 200 t (Odzak *et al.*, 1999). The recent data show that the mercury level in mussels *Mytilus galloprovincialis*, taken in the vicinity of the plant, are higher than at other stations in the Bay, but still bellow the maximum permitted level (Odzak *et al.*, in press). Trace metals concentration in surface sediments shows contamination of the entire Bay by lead (25-45 mg Pb kg^{-1}), and of a limited part by cadmium (0.8 mg Cd kg^{-1}) (Bogner *et al.*, 1998; Ujevic *et al.*, 1998; Ujevic *et al.*, 2000). In any case, harvesting of shellfish from the Bay has been prohibited due to microbial contamination.

Concentration of faecal indicators in the surface layer is higher than the permissible limits for bathing and recreational waters almost over the entire Bay (Krstulovic and Solic, 1991). As a consequence, the most attractive beaches of the area are not safe for recreational use, resulting in great losses for tourism.

The Brač and Split Channels

The Brač Channel is located between the mainland and the island of Brač. The Channel is narrowest, 5 km, along the central part of the island of Brač, and widest at the western end, 13 km. The greatest depth of 78 m is in the south-eastern part and 68 in the western part of the channel. The Brač Channel extends westwards to the Split Channel located between the islands of Solta, Ciovo and Veli Drvenik. The volumes of water masses of the Brač and Split Channels are 16 and 12 km^3, respectively.

The Brač and Split Channels represent a uniform basin mainly exchanging water masses with the adjacent sea through three main passages. The exchange of water masses through the Split strait, between the islands of Brač and Solta and the Kaštela Bay is negligible. The average time of water mass renewal has been estimated at 2.25 months (Margeta and Baric, 1996).

The hydrologic system of the Brač and Split Channels is complex and variable. The area of the Brač and Split Channels is relatively abundant in fresh water. Estimated average yearly fresh water inflow is 2,510.78 million m^3. The largest source of fresh water is the Cetina River (average flow 55.22 m^3 s^{-1}). The main feature of the fresh water inflow is its high fluctuation depending on precipitation in the hinterland.

Temperature and salinity data show that the entire area is horizontally homogeneous throughout most of the year. Salinity ranges mainly from 37‰ to 38‰. The temperature varies depending on the season, and ranges from 10 to 16.5 °C at the bottom, and from 10 to 25 °C at the surface. In the period from April to October a thermocline is formed at the depth of 10 to 20 m below a well mixed surface layer. The sea transparency ranges from 12 to 23 m (Tudor *et al.*, 1990; Tudor *et al.*, 1991). The impact of fresh water is limited to an area in the vicinity of inflows and extends depending on the intensity and direction of local wind and current flows.

Concentrations of ammonia (annual ranges 0.14-3.10 mmol m^{-3}), nitrates (annual ranges 0.00-1.80 mmol m^{-3}), ortho-phosphates (annual ranges 0.000-0.156 mmol m^{-3}) and ortho-silicate (0.14-6.88 mol m^{-3}) in the Brač Channel are relatively low and show uniform distribution considering both the depth and the year seasons, indicating the oligotrophic condition of the channels in terms of nutrient concentrations (Baric *et al.*, 1998). Oxygen saturation varies seasonally in a narrow range: 95-110 % and 85-100 % in the surface and bottom layers, respectively (Baric *et al.*, 1998).

A long-term study of the phytoplankton in the Channels shows that the phytoplankton community is rather undisturbed (Marasovic, unpublished data) without any sign of eutrophication. Concentration of Chlorophyll a varies between 0.09 and 2.49 mg m^{-3}, with maximal values in March and minimal at the end of September (Baric *et al.*, 1998). However, studies of phyto-benthic communities indicated changes in the vicinity of the sewage outlets of urban waste waters. A total number of species has been reduced, while Chlorophite species percentage has increased at the expense of Rhodophyta species which are sensitive to the contamination by urban wastewater (Span and Antolic, 1997).

Microbial pollution is only recorded in the coastal area in the vicinity of the towns of Split and Stobrec due to discharge of untreated urban waste water via numerous outlets. Data on trace metals concentrations in the surface sediments

Table 1. Estimated load of the Kaštela Bay by organic matter, expressed as BOD_5, suspended matter, and inorganic phosphorus and nitrogen from different sources (Baric *et al.*, 1998)

SOURCE	BOD_5 ($t\ y^{-1}$)	Suspended Solids ($t\ y^{-1}$)	Pinorganic ($t\ y^{-1}$)	Ninorganic ($t\ y^{-1}$)
Domestic wastewater	2,226	2,431	14.1	64.8
Industrial wastewater	1,562	954	3.1	14.4
Storm water	984	4,920	–	–
Air deposit	–	–	1.2	9.6
Underground water	205	89	–	–
Surface runoff	27	87	6.1	16.0
Rivers	388	1,419	6.5	55.2
TOTAL	5,392	9,900	31.0	160.0

show no contamination of the area (Bogner *et al.*, 1998; Ujevic *et al.*, 1998).

Existing sewerage systems in the area

The greatest part of the existing sewerage systems was built in the urban area of Split where approximately 70% of the population is served by public sewerage. In terms of surface area, only 55% of the urban area is covered by the sewerage system. The total length of the sewerage system is approximately 200 km. In the areas of the towns of Solin, Kaštela and Trogir public sewer systems are less developed. They cover only a part of the town nuclei, and only approximately 25% of the population is served by the sewerage system. The total length of the Solin sewerage system is 13 km, and the length of the systems of the towns of Kaštela and Trogir are 31 and 16 km, respectively. Buildings not served by the public sewerage systems have individual, mostly permeable septic tanks.

The public sewers in each of the towns consist of numerous small subsystems; each of them consists of a gravity sewer collecting waste and rain waters, and a coastal outlet discharging into the coastal sea. Industries, such as food and beverages processing plants, including a large brewery, a winery and a slaughter house, metal and chemical processing, discharge their wastewaters directly (without pretreatment) into to the communal sewerage system, or directly into the sea. Because of this, there are several large and more than several hundred small outlets in the area. Obviously, there is no wastewater treatment in the area.

Quantity and quality of wastewater and sources of the sea pollution

The quantity of the urban and industrial wastewaters of the entire area has been estimated at 49,000,000 $m^3\ y^{-1}$ (Margeta and Baric, 1996), of which industrial wastewaters account for approximately 5%. About 60% of that quantity is discharged into the eastern part of the Kaštela Bay, while the remaining part is discharged into the Brač and Split Channels. The Kaštela Bay has been used as a recipient of the urban wastewater since late sixties when the town of Split expended onto the Bay's watershed. The brewery and food and beverages processing plants, discharging into the Bay wastewater rich by organic matter, were constructed in that period, as well. The shipyard and metal processing industry have been discharging their waste- and storm waters, as well as some materials, into the Bay sea over the past 80 years. Apart from direct and indirect discharges of the wastewaters, the sea receives large quantities of wastes from various diffuse sources: (i) deposits from the atmosphere; (ii) runoff from urban areas; (iii) runoff from agricultural areas; (iv) runoff from the watershed area; (v) rivers, as shown for the Bay in Figure 2. The yearly load of the Kaštela Bay by organic matter, expressed as BOD5, suspended solids, and inorganic phosphorus and nitrogen is shown in Table 1 (Baric *et al.*, 1998).

As shown in Table 1, the largest portion of organic matter is discharged with domestic and industrial wastewaters, while the largest portion of suspended solids is arriving with storm waters and from the atmosphere. However, the highest con-

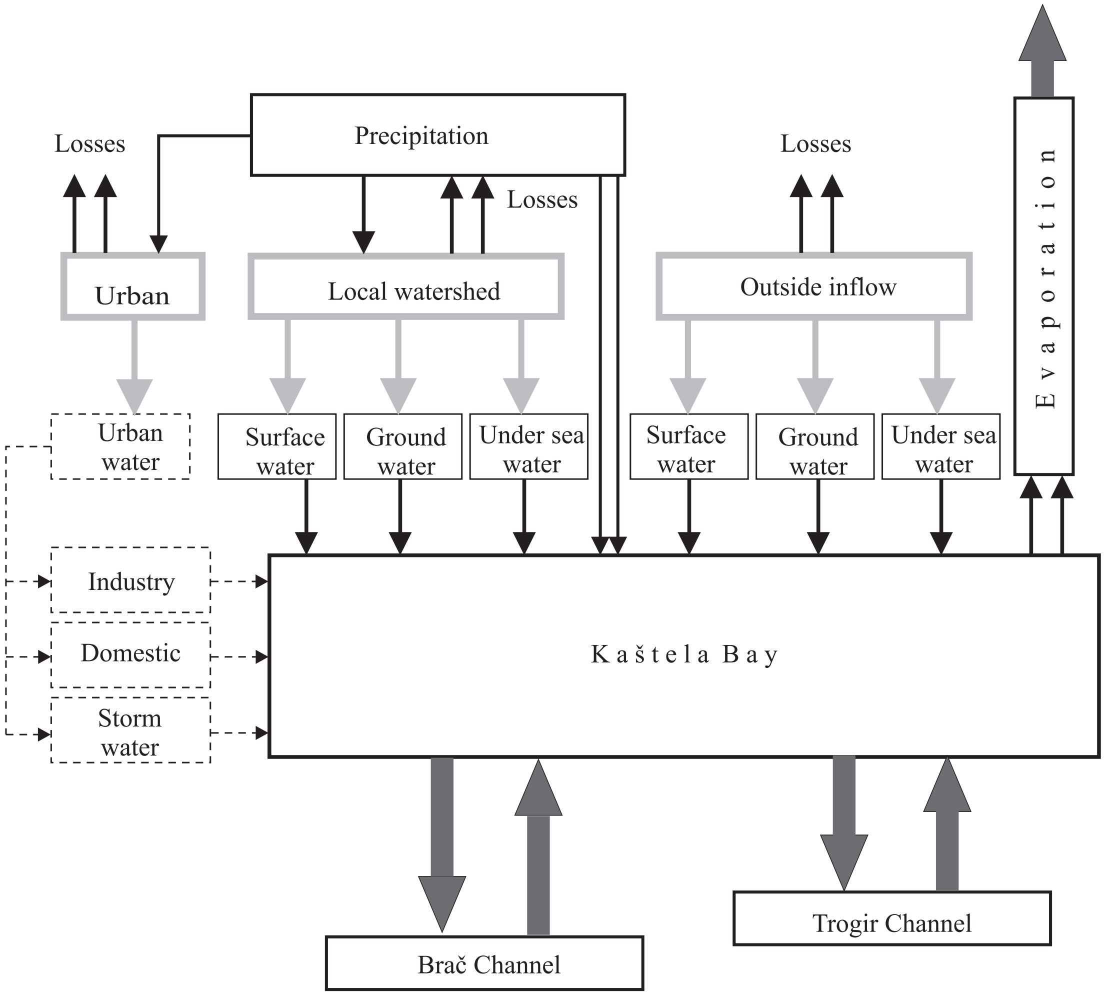

Figure 2. General hydrological scheme of the Kaštela Bay

tribution of inorganic nitrogen and phosphorus is from domestic waste water and rivers.

STRATEGIC APPROACH TO THE PROTECTION OF THE KASTELA BAY AND THE BRAČ AND SPLIT CHANNELS AGAINST POLLUTION FROM LAND-BASED SOURCES AND ACTIVITIES

In order to analyze the problem, a number of studies and projects have been launched. The most comprehensive study was the national project "Environmental Management of the Kaštela Bay". The general objectives of the project, to be achieved by the application of scientific methods, were to:

- identify the causes of the present situation and trends;
- assess their impacts and significance, and
- identify development alternatives for sustainable development.

The specific project objectives were as follows:

- to define the sensitivity, vulnerability and (limited) carrying capacity of the natural resources;
- to introduce standard procedures and parameters into the process of management of natural resources;
- to apply, within the project scientific framework, an integrated approach and principles of sustainable development.

The project was structured in three basic components:

- Models and Modelling;
- Environment and Ecosystem;
- Socio-Economic-Spatial Systems;

resulting in an integrated Synthesis. The major results of the individual project components were as follows:

Methods and Modelling: This sub-project was conceived and implemented as support for the other two sub-projects. Methods were defined, related to database, environment/development scenario, land-use (physical) management, and evaluation of ecosystems by multicrioterional analysis. A number of Decision Support Systems, of a sectoral or issue-specific nature was designed and applied.

Environment and Ecosystems: This sub-project was implemented through research modules related to soil, land, air, freshwater, and marine ecosystems. Each module was elaborated in detail, the sectoral results to be integrated within the scenarios and development options.

Socio-Economic-Spatial System: The sub-project focused on the state, dynamics and trends of development within the given environmental framework, elaborated by the second sub-project. A simulation model was developed and applied. Furthermore, applying the participatory principle, a survey on social and development aspirations was carried out among citizens, the results systematized, analyzed and used. Finally, interrelations among the economic potential and the environmental capacity were studied.

Among the specific results of the project, it should be mentioned that the project implementation and its results confirmed in practice the need for, and benefits from the application of a scientific approach, application of the methodology and tools of integrated coastal management, and of the principles of sustainable development, when dealing with complex environment/development problems, in this case of the Kaštela Bay area. The project widely contributed to the rising of awareness of the general public and authorities regarding the state of the environment and the need for a sustainable development. Its Socio-Economic-Spatial component provided a concept for pollution mitigation and reduction and for a future sustainable development, based on:

- establishment of a system of infrastructure aiming at sustainable and efficient liquid and solid wastes management;
- reduction of other sources of pollution by establishment of appropriate treatment facilities;
- recovery and rational utilization of natural and man-made resources;
- proposals for restructuring of the economy by adopting clean technologies, by applying economic instruments such as urban rent, and implementing an environmentally sound system of land use and urban development.

Studies and projects implemented in the 1986-93 period, in addition to their individual achievements, resulted in a well-founded understanding of concepts and strategies to be applied:

a) the causes of deterioration of the socio-economic context and the state of the environment, the resulting impacts and their significance, indicated the need for the adoption and gradual implementation of comprehensive, long-term multi-phase remedial and sustainable development program, to be formulated according to priorities and existing conditions for its implementation,
b) the strategy of the program should be based on an active development concept combined with appropriate remedial actions,
c) the socio-economic studies and the environment/development scenario prepared indicated the need for a radical change of the hitherto development concept, implying a change of strategy of the national and coastal economy due to the new political context of the independent Republic of Croatia, and structural changes during the transition period, applying an integrated approach to coastal development, oriented towards Europe, the Mediterranean region and the world, based on market economy and principles of sustainable development,
d) the conceptual approach to the program should be based on the principles of: (i) sustainable development; (ii) integrated coastal and marine areas management; and (iii) market economy, and
e) as urgent priorities to be included in the long-term program, the design and construction of the urban wastewater collection, treatment and disposal system were identified.

The protection of the coastal sea is obviously one of the most important prerequisites for the sustainable development of the area, also recognized by the local community. It includes the integrated land use management (soil, fresh waters, sea and air) (Margeta, 1997). As mentioned above, the main sources of the sea pollution are wastewaters, domestic and industrial. Therefore the priority is given to the management of all kinds of wastewaters. In order to achieve the long-term protection of the Kaštela Bay and the Brač and Split Channels against urban and industrial waste waters the following strategic approach was applied:

The Kaštela Bay is considered as an ecologically sensitive and socio-economically important area, and for its protection it is necessary to:

- eliminate from the Bay all outlets and outfalls discharging untreated and/or partially treated municipal wastewaters, as well as the leakage from permeable septic tanks;
- eliminate from the Bay all outlets discharging untreated and/or partially treated industrial wastewaters;
- establish a permanent monitoring program of the coastal water.

The Brač and Split Channels, considered as less ecologically sensitive areas, are selected as a recipient of all urban and industrial wastewaters of the area. The selection was done taking into account their relatively high volume and depth, intensive dynamics of water masses, and present biological and ecological conditions which have not, so far, been affected by the waste water discharge.

The wastewater discharge should be performed under the following general and specific conditions:

a. General conditions

1. Construction of appropriate municipal sewerage system(s) for the collection, treatment and disposal of the entire amount of urban and industrial wastewaters of the region.
2. Wastewater disposal via long submarine outfalls ensuring appropriate initial and secondary dilution, and sanitary protection of a 300 m wide coastal sea belt.
3. Use of natural capacities of the marine environment for wastes treatment and application of a minimal level of urban wastewater treatment. The final level of waste treatment should be determined on the basis of monitoring results. The applied level of waste treatment should ensure that negative impacts are avoided.
4. Pre-treatment of industrial wastewaters prior to their discharge into the municipal sewerage system(s) in order to remove substances that can be detrimental to:
   - the operation of a biological treatment plant
   - the usage of the sludge produced at the treatment plant
   - marine ecosystems.
5. Elimination of all existing uncontrolled coastal outlets in the area.

b. Specific conditions

1. *Studies for the sitting and design of the submarine outfalls*
   A detailed study of hydrodynamic, physical and biological characteristics of areas proposed for the location of submarine outfalls have been performed in order to get appropriate information for the sitting of diffuser and the construction of outfalls.
2. *Baseline study*
   Since the final treatment level will be determined upon the results of systematic monitoring, before the construction of the sewerage system(s) a baseline study of physical, chemical and biological characteristics of the Bay and Channels have been performed. This study will be used as a reference for the comparison with the monitoring data in the process of assessing the impacts of wastes discharge on the marine environment.
3. *Design and construction of sewerage systems*
   In order to ensure the collection, efficient treatment and disposal of all wastewaters, and to avoid negative impacts, the best available knowledge, materials and technology have been suggested for use in the design and construction of the systems. The micro-location of diffusers should be determined on the basis of a detailed study of hydrodynamic, physical, chemical and biological characteristics of potential micro-locations.
4. *Efficient management and maintenance of the sewerage systems*
   Establishment of efficient management and maintenance of the sewerage systems is the key element of the effective protection of the environment. Efficient organisation and experienced, well trained and adequately paid staff are prerequisites for ensuring permanent and proper functioning of the sewerage systems.

5. *Public participation*
   The public (general public, NGOs, scientific community, etc.) should be the main promoter of protection measures, as well as proofreader of all activities, already undertaken or planned, for the protection of the environment. Therefore, it is necessary to involve the public in the development of the project at the earliest possible stage.
6. *Monitoring and information*
   Feedback information on the environment is necessary for appropriate management of the sewerage system(s). Therefore, the monitoring of marine environment, as well as of effluent quality should be and partly have been established. In addition, an appropriate information system to inform the general public, the scientific community and other interested parties about all achievements and planned activities should be developed.
7. *Computer-based Decision Support System for Coastal Water Resources Management*
   A computer-based Decision Support System (DSS) would transform the monitoring data together with other relevant information into a form understandable to decision makers, enabling them to undertake environmentally sound decisions regarding the wastewaters management. This tool is important in decision making related to the protection of the environment, particularly in this case when the final treatment level will be achieved by a step-by-step approach using feed-back information on the environment.

Long-term objectives

The following long-term objectives should be achieved by the fulfilment of the above listed conditions:

a. Sanitary quality of the coastal sea

The coastal sea belt, 300 m wide in the entire area, should be sanitary clean and safe for bathing and recreation in all weather conditions. It means that at many locations in the coastal area the sanitary quality of the sea should be improved.

b. Aesthetic value of the sea water

The aesthetic value of the sea water in the coastal belt should be unaffected by the discharged wastewaters which implies the improvement of the water quality at most locations, which are presently under the impact of small outlets. Only a slight increase of turbidity may be expected in the wider zone of the channels near the diffuser(s) location.

c. Benthic communities

Disturbed benthic communities in the coastal region should be recovered, particularly in the entire Kaštela Bay, but the communities in the vicinity of the submarine diffusers will be completely destroyed.

d. Eutrophication

The discharge of urban waste would increase the eutrophication in the Channels, resulting in the increase of primary productivity and phytoplankton biomass, as well as slight changes in the structure of phytoplankton community, but the “red tide”, oxygen depletion in the bottom layer (except in the vicinity of the diffuser) and other accompanying phenomena should be avoided. At the same time, a gradual improvement is expected in the Bay.

CONCEPTUAL SOLUTION OF THE SEWERAGE SYSTEM

The long-term solution of the sewerage system, developed on the basis of a detailed analysis of ecological, technical and economic parameters, envisages the construction of two sewerage systems, one for the Split-Solin area (Margeta 1990) and a another one for the Kaštela-Trogir area (Margeta, 1992) (Figure 3). Each system has a separate sewage system, normally consisting of two pipelines, one carrying wastewater and other surface water. Each sewerage system consists of a drain system and pump stations, a central wastewater treatment plant, and a corresponding submarine outfall. The Split and Solin wastewaters would be treated at the central plant “Stupe” and discharged into the Brač Channel in front of the town of Stobrec. The wastewaters of the Kaštela and Trogir area would be collected and treated at the treatment plant located in the central-southern part of the island of Ciovo and discharged into the Split Channel in the front of the village of Mavarscica.
The development of each sewerage system has been planned so as to be executed in several phas-

Table 2. Hydraulic load of the wastewater treatment plants of "Stupe" and "Ciovo" at the end of the first phase

	Q_{aver}- summer	Q_{aver}	Q_{rain}
"Stupe" treatment plant			
$m^3\ day^{-1}$	161,568.0	–	–
$m^3\ h^{-1}$	7,732.0	8,352.0	15,804.0
$m^3\ s^{-1}$	1.87	2.32	4.39
"Ciovo" treatment plant			
$m^3\ day^{-1}$	35,888.0	–	–
$m^3\ h^{-1}$	1,494.0	2,340.0	3,087.0
$m^3\ s^{-1}$	0.415	0.650	0.864

es. The system segments constructed gradually will function in an adequate manner and form a satisfactory technical-technological unit in compliance with the legal and other constrains, including EU Directives (91/271/EEC), at the same time being one of the construction phases of the integrated sewerage system. The first phase of both systems consists of the construction of a primary wastewater treatment plant and main collectors together with accompanying pump stations. The second and further phases envisage the construction of secondary sewers and connectors, and, if necessary (based on the results of the monitoring program), the secondary or higher-level of wastewater treatment. The gradual approach to implementation would enable optimal sea protection considering the negative impacts and the economic potential of the region. At the moment it is impossible to define a precise time-table of the project development since the implementation depends on a number of political, socio-economic and ecological factors that will change with time. Namely, we must not forget that this is a country that has only recently come out of war, and is in transition from communist to capitalist social system, as well as in the process of approaching the EU. Such a situation hinders safe planning as it is impossible to predict the intensity of population growth, industrial development, or the dynamics of construction of the drain system, and especially of secondary drains. Thus, the step-by-step approach is the only reliable and efficient approach to problem solution.

The adopted plan anticipates the construction of each new step in accordance with:

- the results of the previous step;
- newly acquired data and information;
- new local, national and international requirements and needs;
- newly developed technologies;
- economic possibilities;
- organizational and other capacities of local communities and organizations.

The aforementioned approach can be achieved through the application of the proposed integrated approach using an adequate DSS.

The hydraulic load of the waste water treatment plants of "Stupe" and "Ciovo" at the end of the first phase is presented in Table 2. A long submarine outfall (3,230 m long and 1,400 mm in diameter), with a 400 m long diffuser at the sea depth of 42 m is envisaged in the first phase at the treatment plant of "Stupe". If a biological treatment is applied in later phases, the outfall may be shorter (930 m) and of a smaller diameter (1,340 mm). With a length of 400 m the diffuser will end at the sea depth of 32 m. At the treatment plant of "Ciovo" the primary treatment requires a submarine outfall 2,400 m long and 900 mm in diameter. With a length of 400 m the diffuser would end at the sea depth of 52 m. The same outfall would be used in case of a secondary treatment. The planned step-by-step construction of the wastewater treatment plant and submarine outfall enable the simple adaptation to future needs and requirements in order to comply with the increase

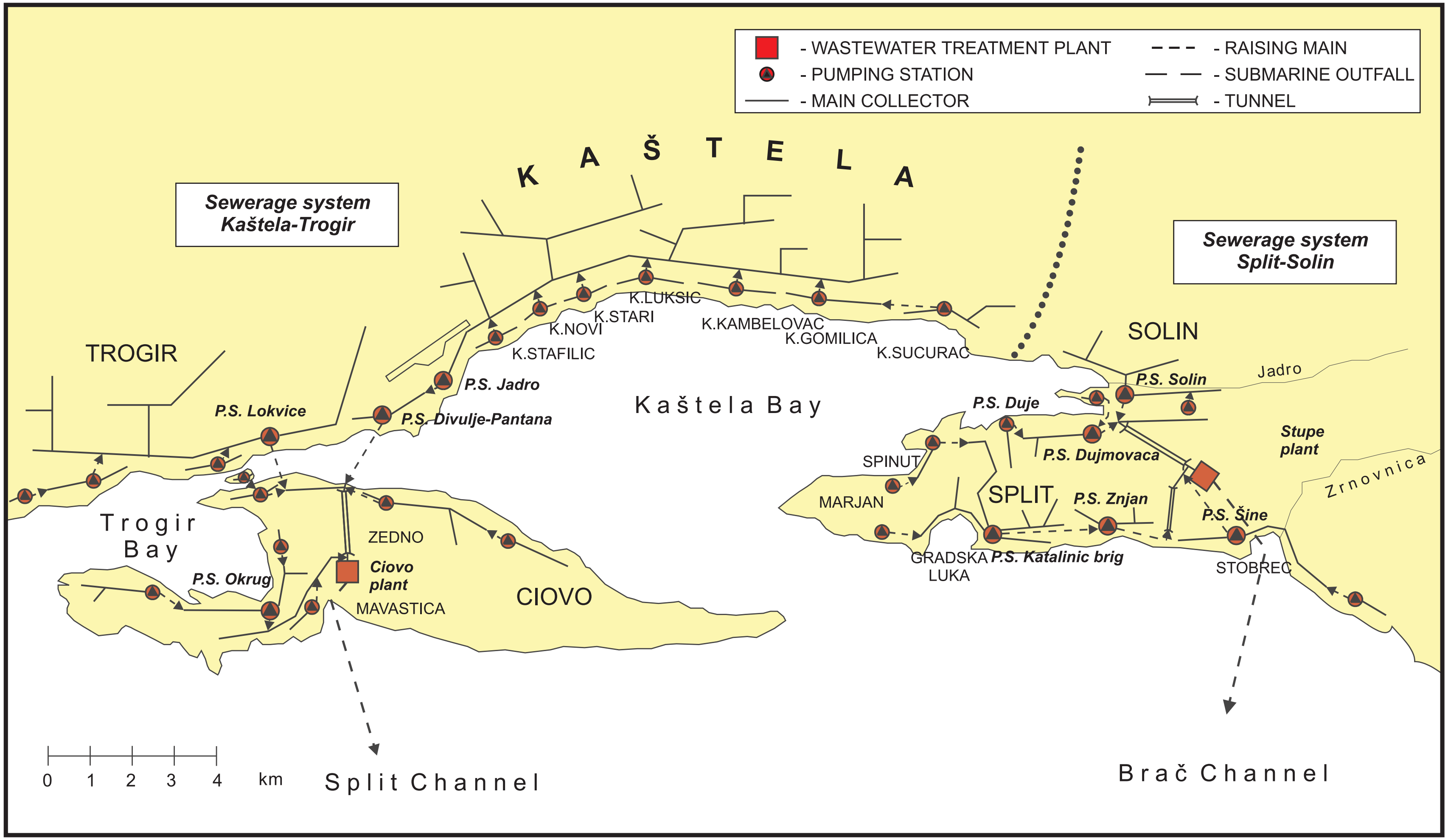

Figure 3. Concept of a long-term solution of the sewerage system in the Kaštela Bay area

of wastewater quantity, as well as sustainable development criteria.

Industrial wastewaters treatment is envisaged in two ways: (i) by treatment at the central wastewater treatment plant; and (ii) locally, by treatment at own treatment plant. Namely, all industrial wastewaters, before being discharged into the sewerage, must meet trade effluent discharge standards, except for BOD_5. All industries incapable of meeting this standard must treat their wastewaters prior to discharging into the public sewerage system.

"ECO KAŠTELA BAY" INVESTMENT PROJECT

In order to implement the mentioned adopted conceptual solution for the management of wastewaters in the area, a project entitled "ECO KAŠTELA BAY" has been developed. The first phase of project is worth about 140,000,000 US$, while total cost is much higher. The project envisages the construction of the main elements of the sewerage systems in order to divert the wastewaters from the Kaštela Bay into the Brač and Split Channels. In the western part of area, the system includes a main collector with accompanying pumps along the northern coast of the Kaštela Bay, a treatment plant, a tunnel through the Ciovo Island, and a submarine outfall in the Split Channel. In the eastern part of the area (towns of Solin and Split) the system consists of a main collector with accompanying pumps in the eastern part of the Kaštela Bay, a hydrotechnical tunnel, a treatment plant, and a submarine outfall in the Brač Channel. The realization of the sewerage systems would be the first step towards the protection of the Kaštela Bay. These selected structures ensure that each sewer system can function as a separate and complete technological system which secures environmental protection and high standards for the users of these systems. This system also ensures the use of the coastal sea in accordance with the legislation and development plans.

The project has a number of components, each of which will produce some favourable environmental effects. Those are:

- Wastewater treatment plant "Stupe" and the belonging submarine outfall: It is certain that this will be the component to have the greatest merit in preventing further pollution of the Kaštela Bay, as well as in eliminating the pollution of the coastal strip of the town of Split. All the wastewaters of the towns of Split and Solin, hitherto discharged into the Kaštela Bay, will now be treated and discharged into the Brač Channel through a long submarine outfall.
- Split-Solin sewerage system extension and improvements: The work on the extension and improvement of the Split-Solin sewerage system will include the interception of all wastewaters now discharged into the Kaštela Bay from this area, and their collection in the "Stupe" wastewater treatment plant, which will prevent further pollution of the Bay. Also, the wastewaters from the part of Split hitherto discharged locally into the Brač Channel will be intercepted and collected at the "Stupe" plant.
- Wastewater treatment plant "Ciovo" and the belonging submarine outfall: This component will contribute greatly to the prevention of further local pollution of the Kaštela Bay from the Kaštela area, as well as of the Trogir Bay form the Trogir area. All the wastewaters of the towns of Kaštela and Trogir, hitherto discharged into the Kaštela and Trogir Bays, will now be treated and discharged into the Split Channel through a long submarine outfall.
- Kaštela-Trogir sewerage system extension and improvements: The work on the extension and improvement of the Kaštela-Trogir sewerage system will include the interception of all wastewaters now discharged into the Kaštela and Trogir Bays from these areas, and their collection at the "Ciovo" wastewater treatment plant, which will prevent further pollution of the Bays.

In addition to the waste water management, the project contains another component dealing with the freshwater supply of the western part of the area. It plays a double role. Besides the improvement of the freshwater supply in the western part of the area, lacking fresh water, particularly in the summer season, it will enable further economic development, as well as increase the water consumption, ensuring necessary funds to pay back the international loans. The project is implemented by a newly formed agency "Eco- Kaštela bay", established by the local administrations included in the project, the Croatian Water Authorities, and the local water and sewerage company.

CONCLUSION

The long-term solution of waste water management can be implemented step-by-step applying the build-on approach. Initially, the primary level of waste water treatment will be implemented and, if necessary, it will be upgraded, depending on the impacts of waste water discharge on the marine environment and development of the sewerage system and quantity of wastewater collected to the treatment plant. Such approach would require an intensive monitoring program, but would ensure the maximal and safe use of the marine environment for the additional wastewater treatment. It would secure a rational use of limited financial resources and protect the marine environment. Implementation of the project would have significant beneficial impacts on the social and economic conditions in the area by resolving the existing conflicts and enabling the development of tourism and other economic activities.

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