# Chapter 3 Consideration for Environment

## 1 General

### 1.1 Water Quality

Water quality means the properties of water and its various physical characteristics (water temperature, salt content, transparency, turbidity, etc.), chemical characteristics (pH, concentration of nutrients, dissolved oxygen (DO), chemical oxygen demand (COD), etc.) and biological characteristics (chlorophyll, organic materials, etc.).

Water quality changes biologically and chemically, and physically moves and diffuses together with a medium (seawater). It changes from time to time by absorbing external energy (tides, meteorological phenomena, river discharges, etc.), and the characteristics may vary daily or hourly. In addition, the spatial distribution of water quality shows local characteristics and at the same time has dispersion effect to make even distribution in the system (**Fig. 1.1.1**).[1] It is important that even when each water quality item changes, it is able to maintain a range of appropriate values.

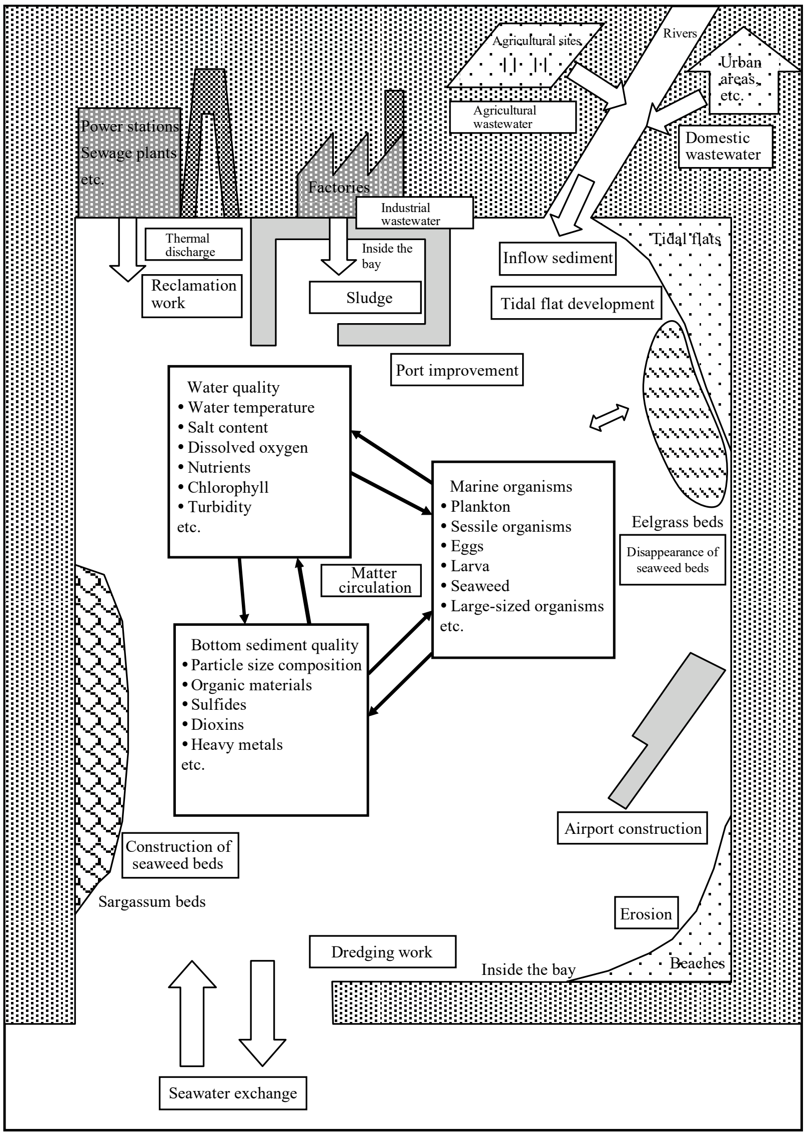


**Fig. 1.1.1** Relationship between Water Quality, Bottom Sediment Quality and Marine Organisms[1]

The Basic Environmental law stipulates that “the water quality criteria for water areas desirable to preserve human health and life shall be specified,” and specifies “environmental water quality standard concerning the protection of human health (health items: 27 water quality parameters including cadmium, but excluding fluorine and boron in coastal waters )” and “environmental water quality standard concerning the conservation of living environments (11 water quality parameters in total for coastal waters: pH, COD, DO, coliform group, n-hexane extracts, total nitrogen, total phosphorus, total zinc, nonylphenol, linear alkylbenzenesulfonate and its salt, bottom layer DO)," in particular. In 2016, bottom layer dissolved oxygen (bottom layer DO) was added to the living environmental parameters in order to help the survival of fishes and preys in the bottom layers of water areas, and conserve and restore areas where populations of aquatic organisms utilizing the bottom layers can be conserved through adequate reproduction.

Other water quality criteria in water areas include environmental criteria based on **the Act on Special Measures concerning Countermeasures against Dioxins** and non-statutory criteria such as water quality criteria for fisheries set forth to maintain the habitation and breeding of useful aquatic organisms, continue unhindered fishery operations and retain the economic value of fishery marine products, etc. Water criteria for fisheries specify the standard values for organic materials (11 parameters including COD) and toxic materials (63 parameters including cadmium). Moreover, water quality criteria for bathing areas have been summarized by the "Council to Discuss the Quality of Comfortable Bathing Areas," which specify the amount of feces-origin coliform groups, the existence of oil slicks, COD, transparency, etc.[2)]

## 1.2 Sediment Quality

Sediment quality means properties of sediments and deposits on the sea bottom and tidal flats in tidal zones reflecting the long history of the environment, and can be used as a time-integrated environmental indicator that reveals the history of long-term variations and evidence of disturbances by events in contrast to the water quality.[1)] Therefore, the vertical structure of the bottom sediment quality deposited beneath the seabed also provides important information as well as the bottom sediment quality on the surface of the seabed. Furthermore, beyond water quality, spatially local distribution is another characteristic of bottom sediment quality.

In regard to the criteria for sediment quality, the Ministry of the Environment's **Guideline for Processing, Disposal and Others of Sediment Quality** specifies the concentration of mercury, PCBs and dioxin in the sediment of which aqueous concentration is at a level not harmful to human health as the elimination criteria of sediment quality. For sediment quality, prohibition against disposing sediments from sea bed exceeding the criteria and approval for sea disposal of dredged sediment and other materials are judged based on the environmental criteria per **the Act on Special Measures concerning Countermeasures against Dioxins** and **the Act to Prevent Marine Pollution and Maritime Disasters** (Act on Prevention of Marine Pollution and Maritime Disasters). As for water quality criteria for fisheries of the sediment quality, there are criteria restricted by COD, the content of sulfides and other materials, and criteria restricted by dissolution tests for cadmium and other materials.[1)]

## 1.3 Organisms

Marine organisms are the primary component of an ecosystem and exist through interrelationships by means of complex food chains (grazing food chains and detritus food chains) at sea and with spatial and temporal hierarchies (**Fig. 1.3.1**). The survival strategies of marine organisms are the r-strategy type, which stands out in areas with a large amount of environmental variation and rapidly recovers after a decrease in number, and the K-strategy type, which stands out in areas with limited environmental variation and slowly recovers after a decrease in number. When preserving marine organisms, attention needs to be paid to the survival strategies of the target organisms, competing organisms, mixing of alien species and so on.

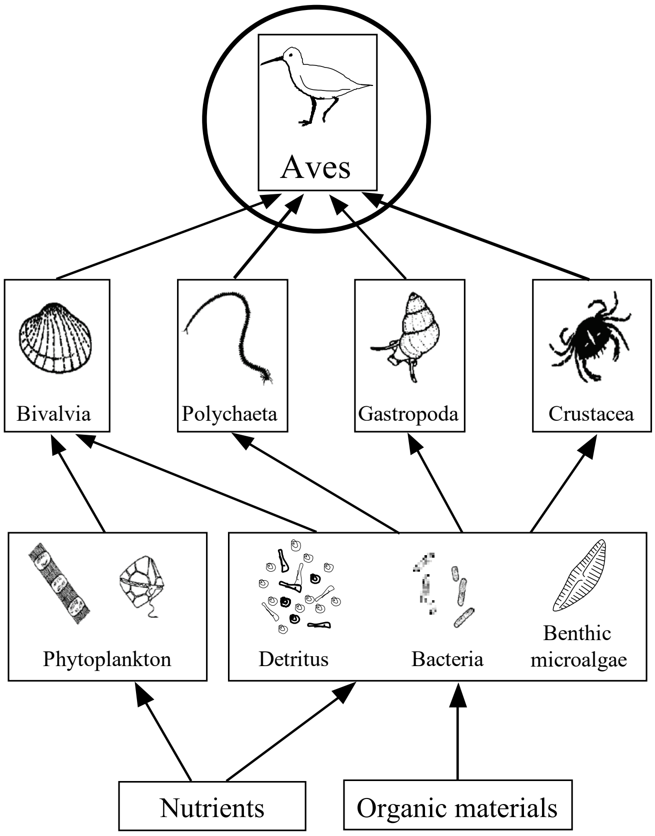


**Fig. 1.3.1** Relationship between Marine Organisms that are Components of Tidal Flat Ecosystems[3)]

## 1.4 Ecosystem

Coastal ecosystems have functions such as habitats for marine organisms, purification of water quality, material circulation, biological production and amenity-oriented functions which are exerted in physical, chemical and biological processes and are made up of complicated relationships, therefore, the results of human intervention cannot be fully predicted. As a result, comprehensive and adaptive efforts for conservation, restoration and creation of these ecosystems are indispensable.[4)]

What characterizes an ecosystem are the relationships between living organisms and abiotic environments (water sediment quality, flow, etc.) and interactions between marine organisms. The relationships between different ecosystems are also important in determining the coastal water environment. It is necessary to try to understand the whole picture when looking at the complex relationships between these elements (**Fig. 1.4.1**).[4) 5)] For consideration of the environment, it is necessary to consider the influences on the notable species and biological community that comprise the ecosystem, as well as extract the environmental factors influencing their survival, growth and breeding, and understand the proper ranges of each of these areas as quantitatively as possible.

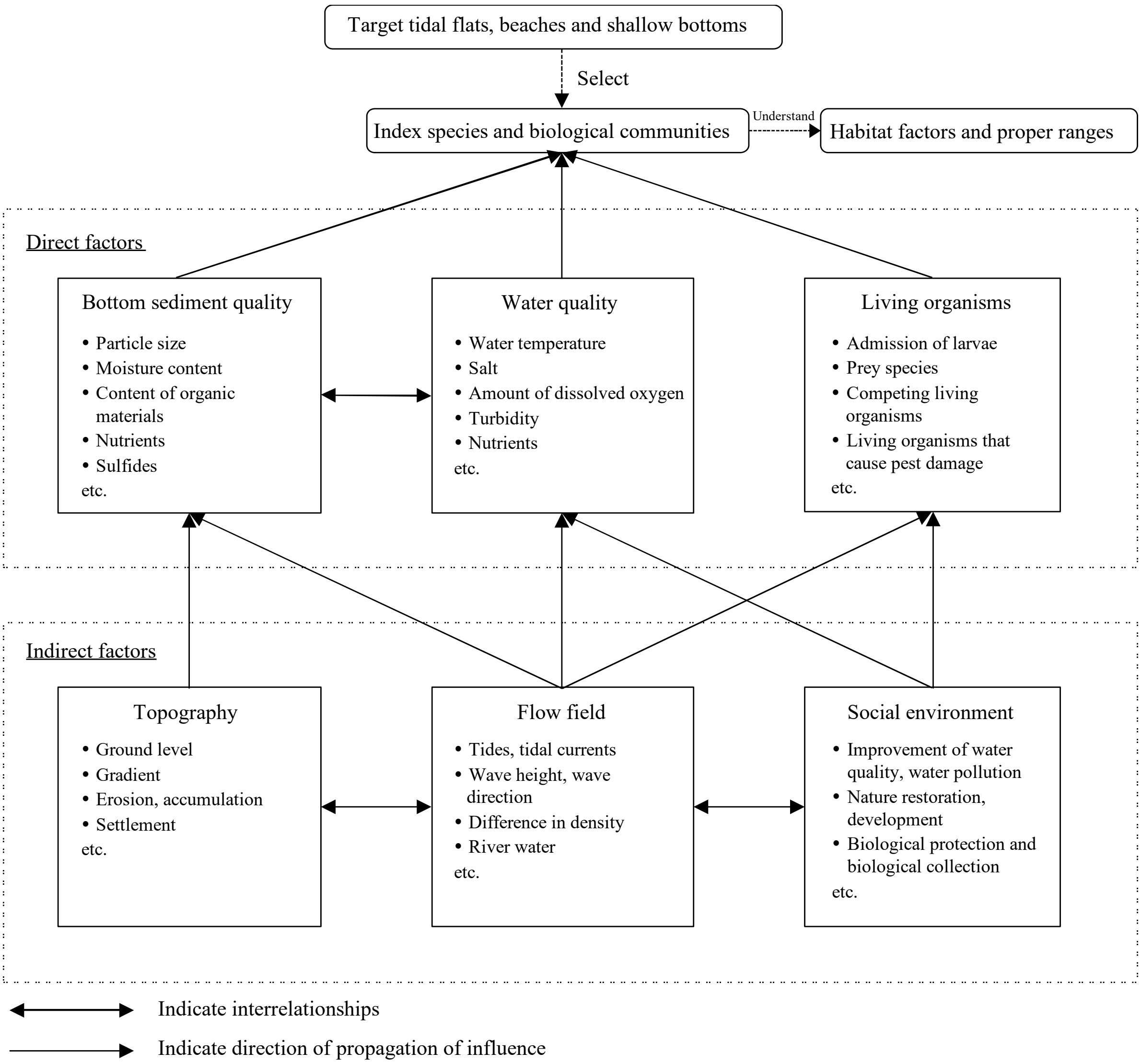


**Fig. 1.4.1** Propagation Flow of Environmental Factors Influencing Species and Biological Communities[6)]

An ecosystem provides ecosystem services (benefits) for regulation, provision and culture, and a variety of marine organisms make the basis of those services (**Table 1.4.1**). As for the variety of marine organisms in particular, **the Strategy for Maintaining Diversity of Marine Organisms** was developed in March 2011 for the long-term utilization of marine ecosystem services. The strategy shows that the diversity of marine organisms supports our "lives and livelihoods."[6) 7)] Among the ecosystem services, the regulating service that absorbs carbon dioxide in the air and stores organic materials in marine sediment, which is provided by the blue carbon ecosystem, is becoming more important since the Paris Agreement (**Table 1.4.2**).[8)]

**Table 1.4.1** Summary of Ecosystem Services

<table>
<tr><td rowspan="2">Supporting services[7)]<br>Supporting services are necessary for the production of all other ecosystem services. Supporting services often exert indirect and very long-term effects on people, while changes in provisioning, regulating and cultural services exert direct and short-term effects on people.</td><td>Provisioning services[7)]<br>Provisioning services are products obtained from an ecosystem and include food, fiber, fuel, genetic resources, chemical substances, natural medicines, materials for ornaments and fresh water.</td></tr>
<tr><td>Regulating services[7)]<br>Regulating services are benefits obtained from the adjustment of ecosystem processes and include regulation of air quality, climate, water and soil erosion, as well as water purification and waste treatment, prevention of diseases, pest control, pollination and protection from natural disasters.</td></tr>
</table>

| | |
|---|---|
| Supporting services include soil formation, photosynthesis, primary production, nutrient salt circulation and water circulation. | **Cultural services**[7)]<br>Cultural services are non-material benefits people obtain from an ecosystem through the improvement of spiritual quality, intellectual development, introspection, amusement and aesthetic experiences, and include cultural diversity, spiritual value, religious value, a body of knowledge, educational value, inspiration, aesthetic value, social value, sense of place, cultural heritage value, amusement and tourism. |

**Table 1.4.2** Distribution Area and Carbon Storage Rate of Blue Carbon and Other Ecosystems[8)]

| | Area ($\times$ 1,000,000 km$^2$) | Arial carbon accumulation rate (average value, data range) (ton C/ha/year) | Global carbon accumulation rate (data range) (carbon Tg C/year) |
|---|---|---|---|
| Blue carbon ecosystems | | | |
| Seaweed beds | 0.33 (0.6) | 0.83, 0.56-1.82 (1.37) | 27.4-44 (82) |
| Mangrove forests | 0.17 (0.3) | 1.39, 0.20-6.54 (1.89) | 17-23.6 (57) |
| Salt marshes | 0.4 (0.8) | 1.51, 0.18-17.3 (2.37) | 60.4-70 (190) |
| Total of the three ecosystems | 0.9 (1.7) | 1.23, 0.18-17.3 (1.93) | 114-131 (329) |
| Other marine ecosystems | | | |
| River mouths, inner bays, areas outside of bays (excluding the above) | 1.8 | 0.5 | 81.0 |
| Continental shelf areas | 26.6 | 0.2 | 45.2 |
| Total of the two above | | | 126.2 |
| Total of the coastal areas | | | 237.6 (454) |
| Ratio of blue carbon ecosystems | | | 46.89 (0.72) |
| Deep sea | 330.0 | 0.00018 | 6.0 |
| Entire marine | | | 243.62 (460) |
| Ratio of blue carbon ecosystems to the entire marine | | | 45.73 (0.71) |

The UNEP Report has been modified. The storage rate is calculated from the amount of organic carbon deposited into the seabed soil per unit area and time. Values in parentheses indicate the maximum value in the data confidence interval.

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# 2 Green Port Structures

## 2.1 General

Green port structures are those that provide basic functions as port structures and which help marine organisms populate in areas such as tidal flats and shore reefs[1)] (**Part III, Chapter 4, 4 Green Breakwaters**, **Part III, Chapter 4, 14.7 Green Revetments**, **Part III, Chapter 5, 2.1.3 Quaywalls** and **Part III, Chapter 5, 5.1.2 Green Piled Jetty**). There are three following configuration types of port structures for coexistence with organisms (**Fig. 2.1.1**):

① Covering type
② Piled jetty type
③ Caisson type

Furthermore, there are three habitat types for organisms added as green port structure

① Sand and silt type
② Gravel type
③ Block type

## 2.2 Structure Type

**(1) Covering type**

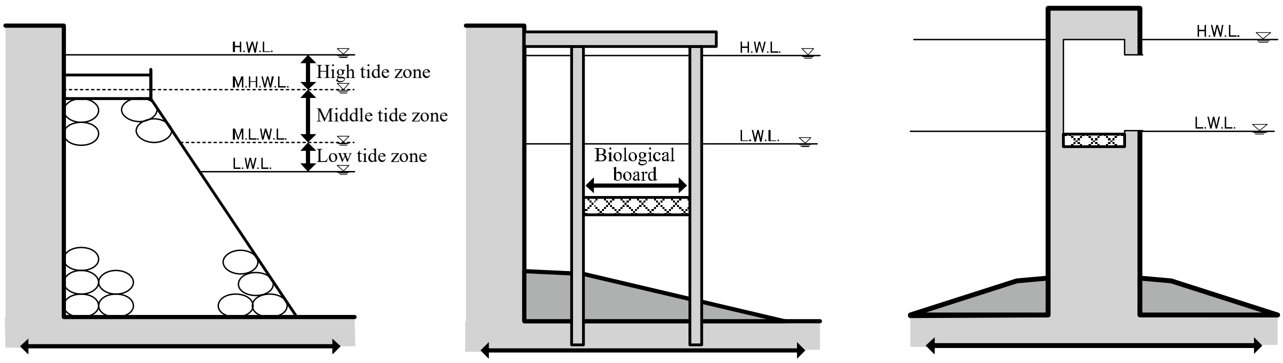
The covering type is a structural type that provides a gentle slope or step-wise structure in front of the port structures or behind of breakwaters, and covers their surfaces with materials such as sand, gravel and blocks. Gentle sloped revetment with coexistence functions with organisms is also classified as the covering type.

**(2) Piled jetty type**

The piled jetty type is a structural type that provides undersea floorboards or similar that serves as a biological board by utilizing the space under piled jetty.

**(3) Caisson type**

The caisson type is a structural type that ensures a habitat by devising a structure to make it easy for organisms to grow in compartments in the caisson.




(a) Covering type (b) Piled pier type (c) Caisson type

**Fig. 2.1.1** Configuration Types of Green Port Structures[1)]

## 2.3 Habitat Type

The habitat type can be selected and applied from the following three types for any structural type. The selection of habitat type depends on the water depth for installation, water quality, oceanographic phenomena and expected marine organisms.

**(1) Sand and silt type**

The sand and silt type utilizes sand and silt as a habitat for living organisms. A habitat set to a tidal zone and deeper than a tidal zone for the covering type is a tidal flat and shallow area, respectively. In addition, the use of sand and silt as a biological board in piled jetty type and caisson type also creates a tidal flat or shallow area.

**(2) Gravel type**

The gravel type uses stone materials as a habitat for marine organisms. The habitat for marine organisms becomes a growth base material for seaweeds and a habitat for sessile organisms depending on the water depth for installation and the environmental conditions.

**(3) Block type**

The block type uses blocks such as algal reefs and fishing reefs as habitats for marine organisms. The habitat for organisms becomes a growth base material for seaweeds and a habitat for marine organisms such as fish depending on the type of blocks.

## 2.4 Development Plan

### 2.4.1 Understanding the Conditions

Green port structures append a habitation function for organisms at the port structures with the assumption that the original functions of the port structures are maintained (**Fig. 2.4.1**). It is also necessary to compile related information such as restrictions on utilization due to ship navigation, berthing and so on in advance.

The purpose of green port structures is to create a habitat for organisms, and thus, effective structures need to be assessed according to the environment of the region concerned. When studying the target organism species, the type of habitat and detailed profiles, it is necessary to understand physical conditions such as the current conditions of the surrounding water surface and waves, conditions of water quality and the habitation situation of marine organisms. Moreover, it is important that the needs of the coastal environment required on the regional level be understood beforehand for effective coordination.

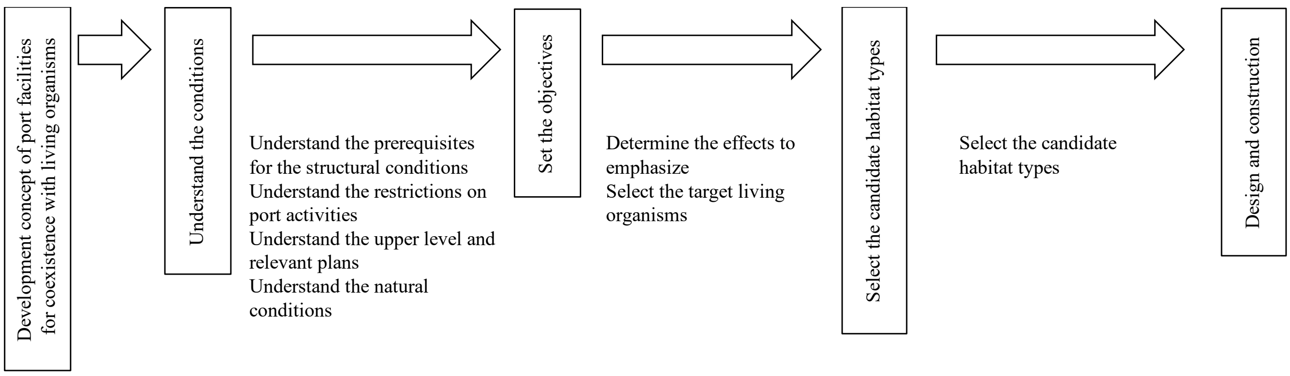



**Fig. 2.4.1** Concept Flow of the Development and Planning of Port and Harbor Structures Symbiotic with Organisms

### 2.4.2 Setting the Objectives

Setting the objectives can be started by determining the effects to emphasize among those expected from the development of green port structures shown in **Table 2.4.1**. Effects obtained from green port structures are divided into two categories: effects obtained from the formation of an ecosystem and collateral effects from the development of bedrock, and they are subdivided into biological, chemical, physical, social and economic effects.

**Table 2.4.1** Major Effects Expected from the Development of Green Port Structure

| Effects obtained from the formation of an ecosystem | |
|---|---|
| Biological effects | Improvement of basic productivity |
| | Provision of a habitat |
| | Provision of egg-laying and incubation sites |
| | Provision of food |
| | Circulation of nutrient salts |
| Chemical effects | Purification of water quality |
| | Reduction of $CO_2$ |
| Physical effects | Weakening of waves and flow |
| Social effects | Education and research grounds |
| | Amenity-oriented grounds |
| Economic effects | Economic effects due to increased interaction among people |
| **Collateral effects from the development of bedrock** | |
| Physical effects | Protection of the coast line |
| Economic effects | Reduction of maintenance and repair costs |

### 2.4.3 Selection of Candidate Habitat Types

It is necessary to select suitable candidate habitat types that serve the purpose in consideration of the structural restrictions on the port structures and the expected effects mentioned earlier. When there is no need to consider structural restrictions and limitations on port administration and utilization for the target port facilities, it is desirable to determine the expected effects and target species and to select the proper habitat types based on the objectives while taking into consideration the natural conditions of the water areas concerned. **Table 2.4.2** shows the main conditions for the selection of habitat types and examples of target species.

**Table 2.4.2** Main Conditions for the Selection of Habitat Types and Examples of Target Species

| Habitat type | Water depth zone | Main conditions for selection | Target species (example) |
|---|---|---|---|
| Sand and silt type | Tidal zone | Relatively calm water surface (where the effects of waves or flow that lead to the outflow of sand are minor)<br>The area should not be a water area where there is a concern for water stagnates and deposits of suspended solids are a concern | [Benthic organisms] Sandworms, clams, Upogebia pusilla, sand bubble crabs, Marcophthalmus japonicas, etc.<br>[Fish] Acanthogobius, Tridentiger obscurus, etc.<br>[Seaweed] Nanozostera japonica<br>[Plants] Phragmites, Suaeda maritima, etc. |
| Sand and silt type | Deeper than the tidal zone | | [Fish] Stone flounder, Paralichthys olivaceus, Portunus trituberculatus, etc.<br>[Other animals] Marsupenaeus japonicus, Squilla, Scapharca broughtonii, etc.<br>[Seaweed] Eelgrass |
| Gravel type | Tidal zone | High concentration of dissolved oxygen suitable for habitats is expected with minor effects of hypoxic environments, river flushes, etc.<br>Where the formation of seaweed beds is expected, lighting conditions (amount of light, transparency) and salt suitable for growing seaweed can be anticipated. | [Periphyton] Serpulidae, white streaks barnacles, periwinkle, mouse chiton, pacific oyster, orange-striped sea anemone, shore crabs, etc.<br>[Seaweed] Green laver, hijiki, etc. |
| Gravel type<br>Block type | Deeper than the tidal zone | | [Fish] Scorpion fish, *Pseudoblennius cottoides*, Rockfish, etc.<br>[Other animals] Henricia nipponica, Anthocidaris, abalone, etc.<br>[Seaweed] Sargassum, undaria, Sargassum tortile, Eisenia, Ecklonia cava, etc. |

[Reference]

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# 3 Conservation and Restoration of Natural Environment

## 3.1 Nature Restoration

To help create a society that can coexist with marine organisms, **the Act on the Promotion of Nature Restoration** became effective in 2003. **The Marine Nature Restoration Handbook**[1] stipulates that nature restoration includes "conservation" to preserve the natural environment we have now, "restoration," targeting past geography, ecosystems and other environmental areas, and "creation," a new goal based on the changed environmental, social and other conditions as a broad interpretation and which does not necessarily demand restoring nature before development (**Table 3.1.1**).

For nature restoration in the broad sense, a variety of technologies such as development of tidal flats and shallow areas, overlaying sand and backfilling borrow pits are available on the water area. For development of tidal flats and seaweed beds, **Part III, Chapter 11, 3.6 Conservation of Natural Environment** may be referred to.

**Table 3.1.1** Definition of Nature Restoration-Related Terms

| Classification | Term | Description |
|---|---|---|
| Conservation | Conservation | To manage so as to conserve the health of habitats for living organisms |
| | Protection | To maintain the present condition |
| | Preservation | To let nature take its course and refrain from human intervention |
| Restoration | Reconstruction | To approximate the previous conditions of once lost habitats for living organisms |
| | Improvement | To purify contaminated habitats for living organisms |
| | Recovery | To manually recover the function of habitats for living organisms |
| Creation | Creation | To manually create habitats for living organisms |

Prepared by referring to 1)

## 3.2 Sand capping

The reasons for the degradation of sediment quality include organification of bottom sediment due to eutrophication of water masses and contamination with toxic chemical substances. The organification of bottom sediment quality is mainly improved by dredging, overlaying sand and improving the bottom sediment quality. Overlaying sand to try to restore a habitat for living organisms as well as improve the bottom sediment quality is often used as a method to restore nature.[2) 3) 4) 5) 6) 7)]

Overlaying sand has the following four main effects: ① it restrains the release of nutrient salts from the sediment during its cycle to reduce eutrophication of the sea water; ② it restrains the hypoxia of the bottom layer by reducing the oxygen demand of the sediment; ③ it reduces the release of toxic chemical substances to the water; and ④ it provides a variety of habitats for living organisms by becoming basis of habitat for benthonic organisms and seaweed as environments for living organisms.

Sustainability of the effects of overlaying sand needs to be adequately considered when planning the overlaying sand[8)] (**Fig. 3.2.1**). Sustainability is obstructed by the outflow of overlaying sand materials due to waves, flow and other forces, sinking due to mixing with the current ground and burial of overlaying sand materials due to deposition of organic substances.

To prevent or reduce the outflow of overlaying sand materials due to waves and flow, it is necessary to understand the influence of waves and flow at seabeds of target area, and to select overlaying sand materials of appropriate grain sizes. If there is not sufficient data to estimate the stability of overlaying sand materials, the stability may be assessed using a numerical model. When the overlaying sand materials are expected to outflow, an adequate thickness of overlaying sand needs to be assessed during the planning stage while considering the amount of outflow and the expected service life.

The bottom sediment of eutrophicated sea area are often soft ground with high organic matter content, and when sand capping is on this soft muddy ground with high organic matter content, the sand sinks into the mud.Even if the sand does not sink immediately after overlaying sand, it may sink after several years by vertical mixing the surface of the bottom sediment due to disturbances from flow and waves. When the overlaying sand materials are expected to sink, it is necessary to assess and estimate the amount of sinking and consider an adequate amount of sand to be injected. It is possible to use hard and steel slags as overlaying sand materials in order to restrain resuspension due to flow and waves as well as the vertical mixing of the surface of bottom sediment.[9)]

For sea area where the burial of overlaying sand materials due to deposits of organic materials is strongly concerned, it is desirable to understand the depositing rate of bottom sediment in advance using sediment traps or other means, and to assess how long the effects of the overlaying sand will persist. For sea area where a large amount of organic materials have been deposited, it will be considered to use coal ash granulated substances which weaken the reduction rate of effectiveness of overlaying sand for the depositing of organic materials in order to retain the overlaying sand effects.[10)]

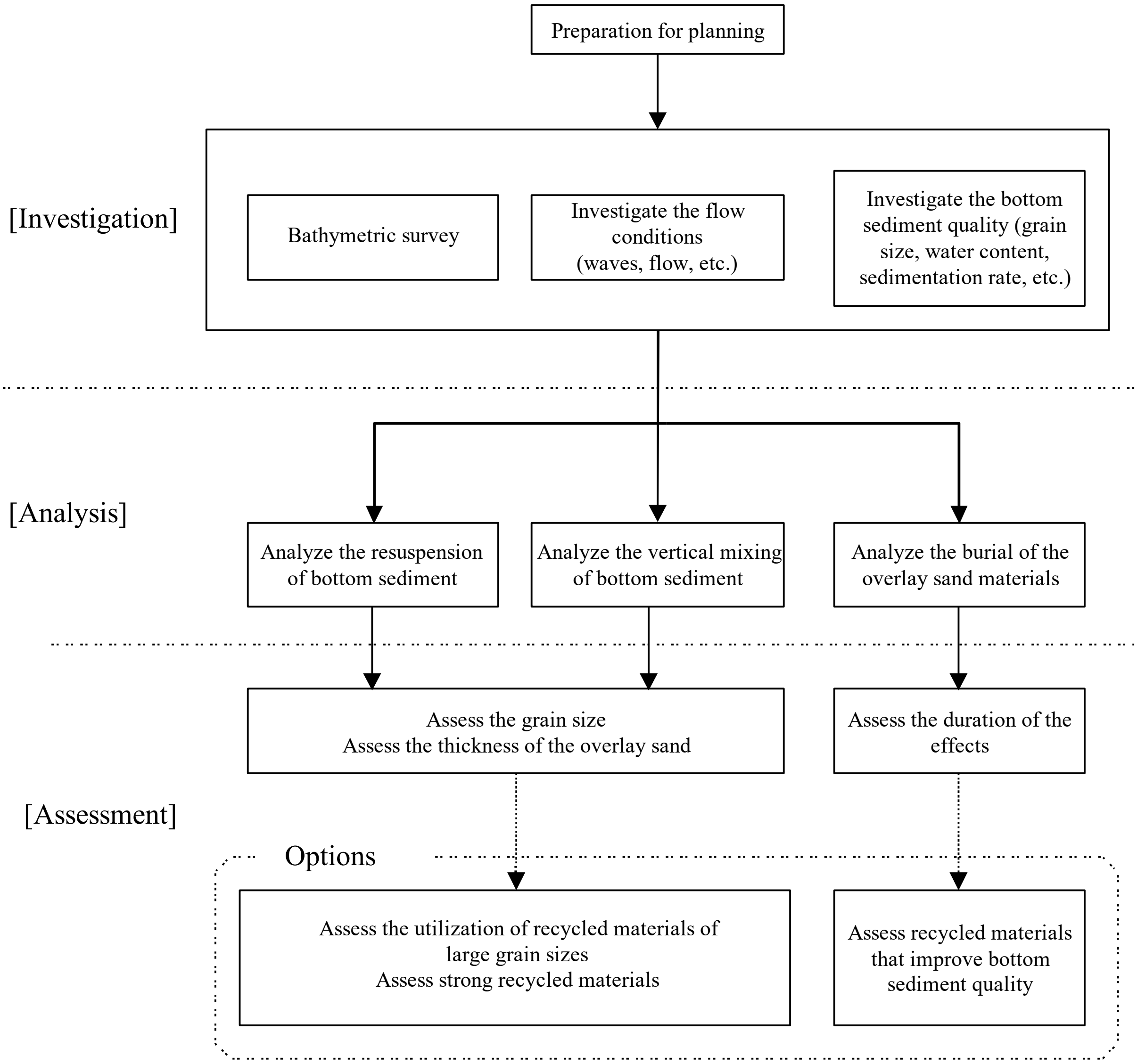


**Fig. 3.2.1** Investigation, Analysis and Assessment of Flow in Planning of Overlaying Sand

## 3.3 Backfill of borrow pits

There are borrow pits of various sizes in domestic coastal areas. These are mainly remains of sea gravel dredging for land reclamation. Borrow pits are classified into the depression type, which is locally and vertically dredged, and the flat type, which extends gently.[11)] This section mainly focuses on the depression type for which improvement to hypoxia is expected through backfilling.

The insides of the borrow pits are pocket-shaped, in contrast to the surrounding water area. In addition, water stagnates in these areas, with organic bottom sediment and other materials accumulating and creating deposits, leading to hypoxia and anoxia accompanied by deterioration of water quality. Hypoxia and anoxia not only negatively affect the living organisms living there, but also result in the release of sulfides from sediment which have become reductive and also negatively affect the surrounding water due to blue tides and other forces (**Fig. 3.3.1**).[12] Backfilling of borrow pits reduces the negative effects to coastal environments, and thus, the improvement of these environments can be expected. The report of the Central Environment Council in May 2005, "**On the method of the sixth water quality total volume control**," and the report of the Council of Transport Policy in March 2005, "**On the basic direction of future port environmental policy**," also stipulate that the improvement of sea area environments should be promoted by backfilling deep-mined areas.[13]

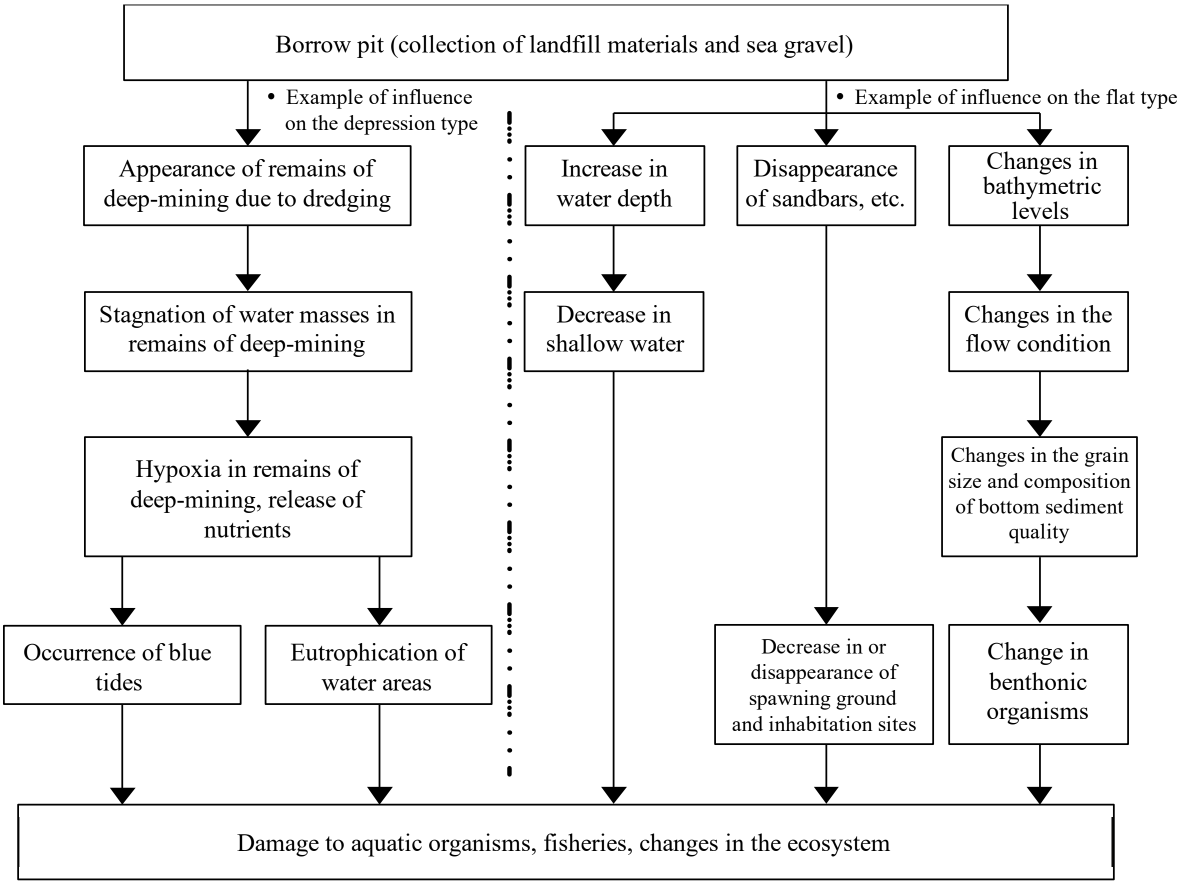


**Fig. 3.3.1** Mechanism in Which Borrow Pits Affect Aquatic Organisms[12]

Examples of restoration through backfilling so far include the offshore of Kemigawa in Tokyo Bay, the Mito District in Mikawa Bay, the offshore of Muromigawa in Hakata Bay, and Nakaumi in blackish water.[14) 15) 16)] Dredged sediment obtained in maintenance dredging of navigation channels and basins is often used effectively as backfill material. When dredged soil is used as backfill material, it may be used after solidifying with recycled materials such as cement and iron and steel slag as solidification material and water soluble polymer and other agents as water absorbent material since it is often rich in organic components, silt clay-like materials and weak dredged soil with a high water content.[17] If such recycled materials are used for backfilling, it is desirable to overlay with soil of good quality after the backfill. When no overlaying sand is used, it is necessary to assess the effects on the environment through dissolution experiments or other means in advance.[18]

In the selection of backfill methods for dredged areas, it is necessary to pay attention to oceanographic phenomenal conditions, construction conditions, such as target area and water depth, construction ability, required thickness of the backfill, and cost, and to consider the influence construction exerts on the surrounding environment. For the impact response given to the surrounding water just after throwing the soil and before the effects of restorations can be seen with a focus on the movement of soil during the backfill work, refer to **Fig. 3.3.2**.

When throwing the backfill material, muddy sea water due to the backfill material itself, deposits to the surrounding seabed, resuspension, diffusion and deposition to the surrounding water of existing sediments may happened (**Fig. 3.3.2** ①, ②, ③). Moreover, when throwing the backfill material, it is possible that hypoxic and anoxic water masses stagnating inside will diffuse to the surrounding seabed (**Fig. 3.3.2** ⑤). In this way, it is desirable to minimize the influence construction exerts on the surrounding environment by understanding and assessing the influence of the construction in advance based on the impact response flow as shown in **Fig. 3.3.2**.

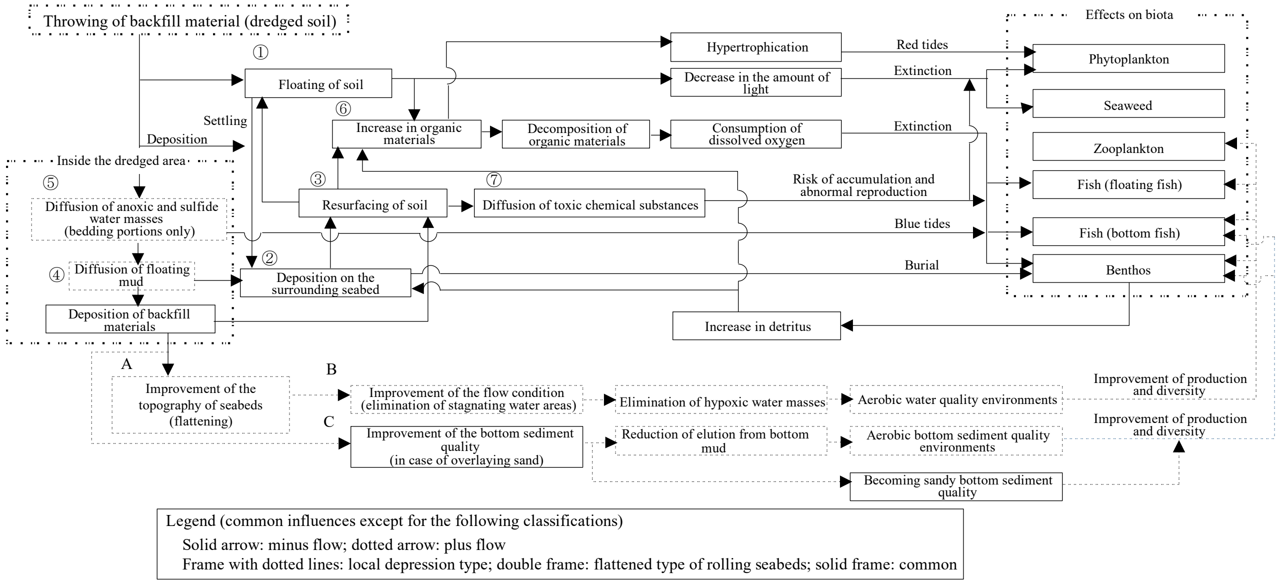


**Fig. 3.3.2** Impact Response Flow to the Surrounding Environment during Backfill Work[11)]

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