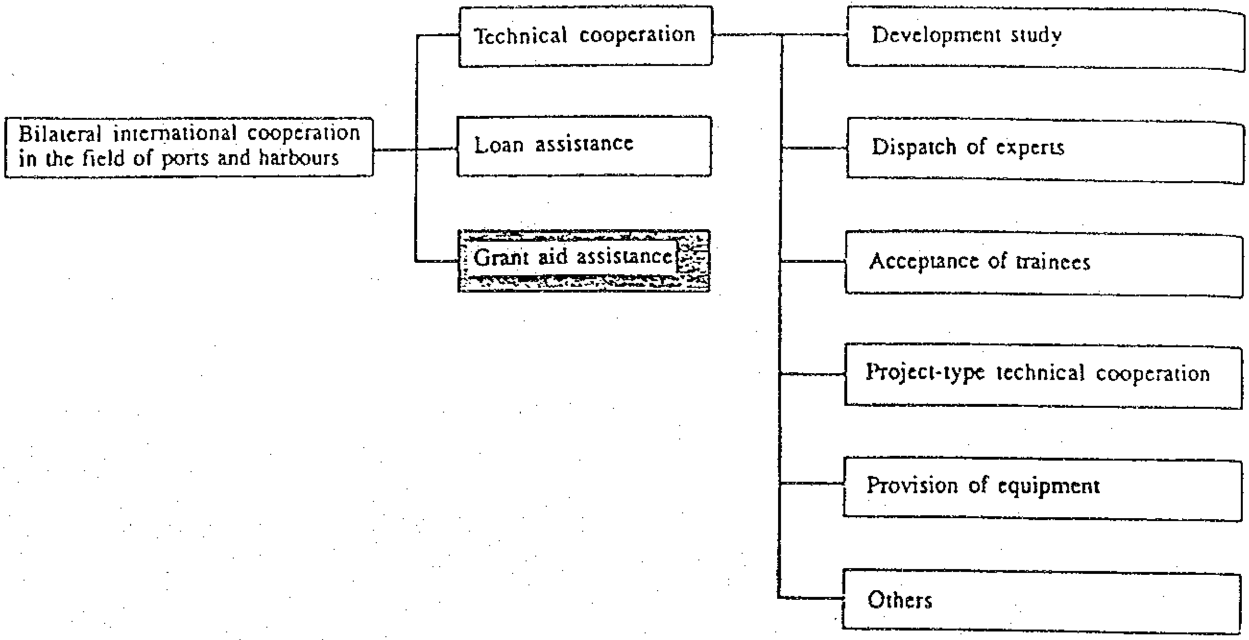
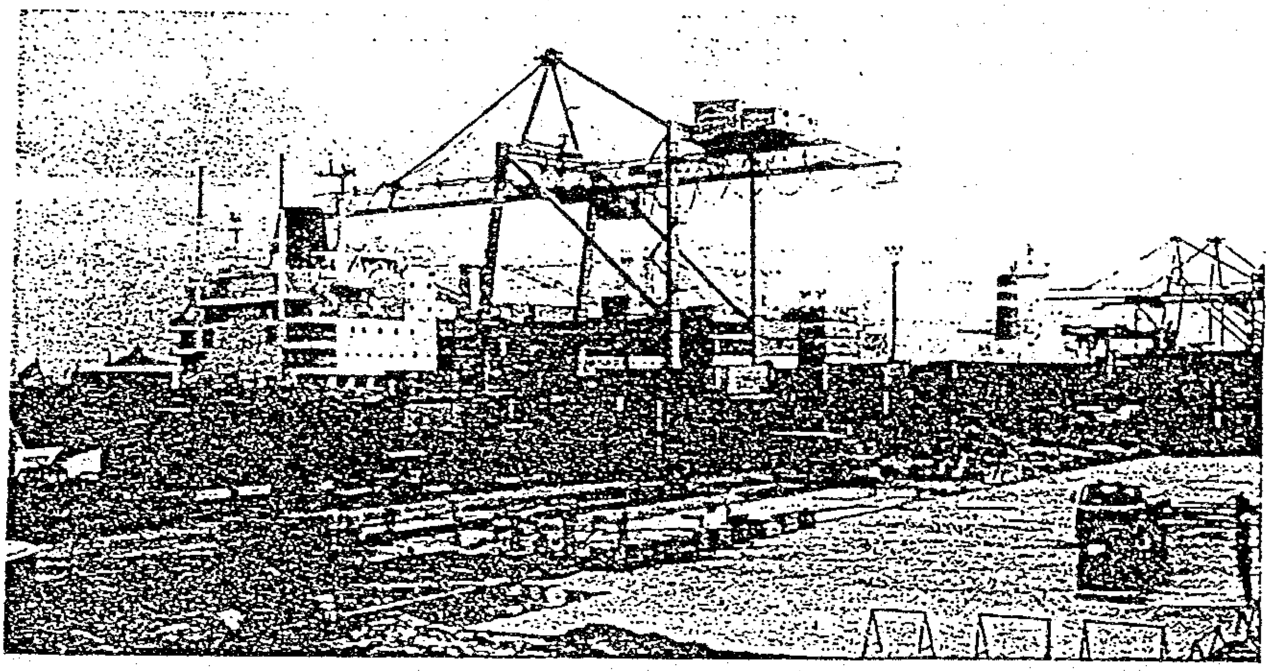
3. Integrated Promotion of Assistance Programs

Bilateral International Cooperation
in the Field of Ports and Harbours (ODA)

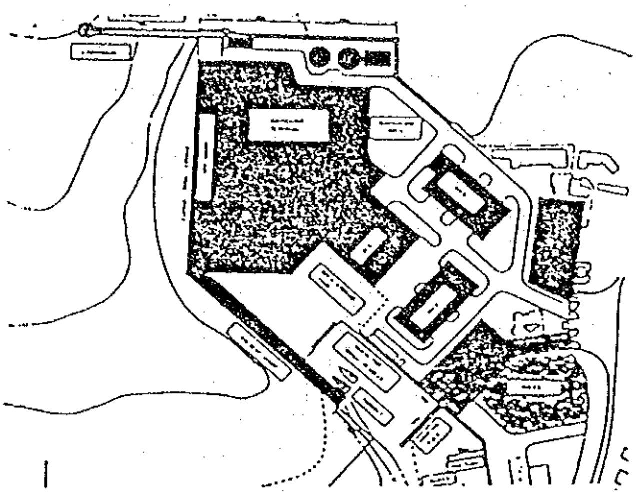


Port Hydraulics Center Project in Mexico (Project-type Technical Cooperation)

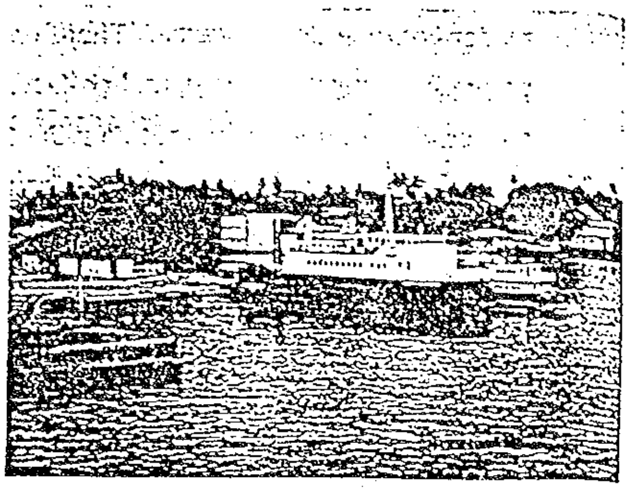
In order to accelerate the self-supporting of developing ports, it is necessary to render continuous assistance. Therefore, it is necessary to apply the Japan's assistance programs comprehensively and collectively. In this connection, we will extend our cooperation in a package that contains assortments of effective programs such as loan assistance, grant aid assistance, and the dispatch of experts.



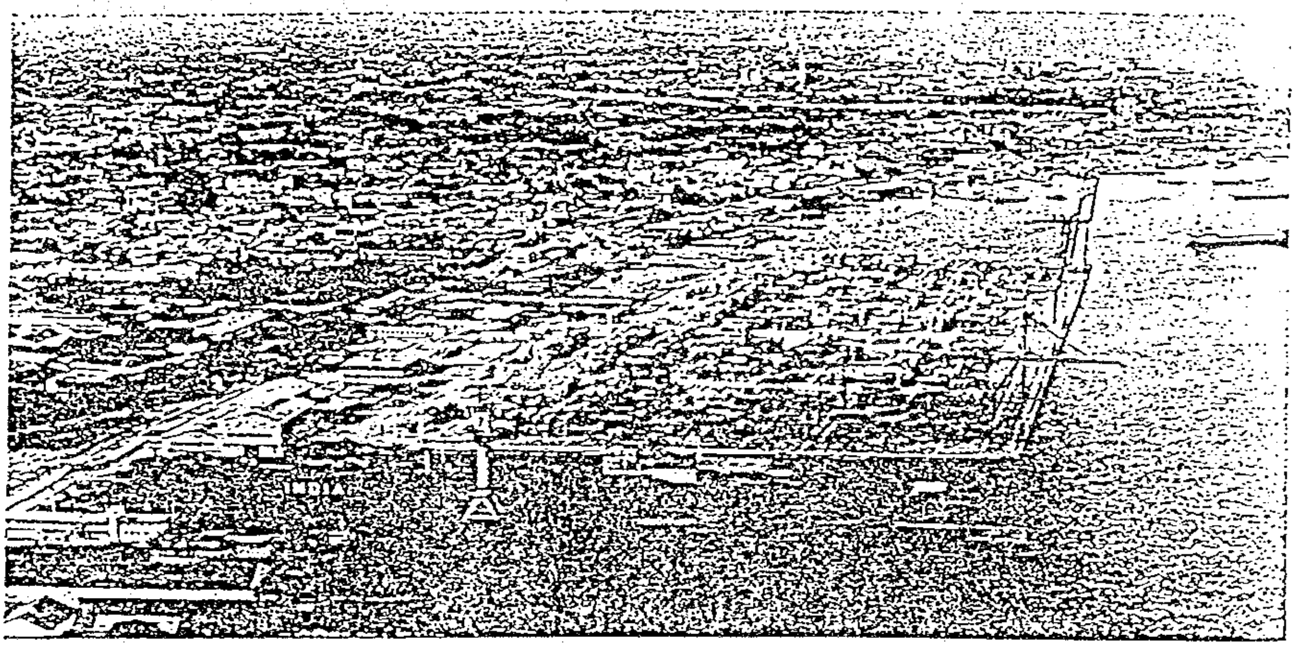
Example of Development Cooperation Project - Trial Pavement of Container Terminal in Port of Colombo, Sri Lanka



Example of Development Study - Master Plan of Port of Apia, Western Samoa

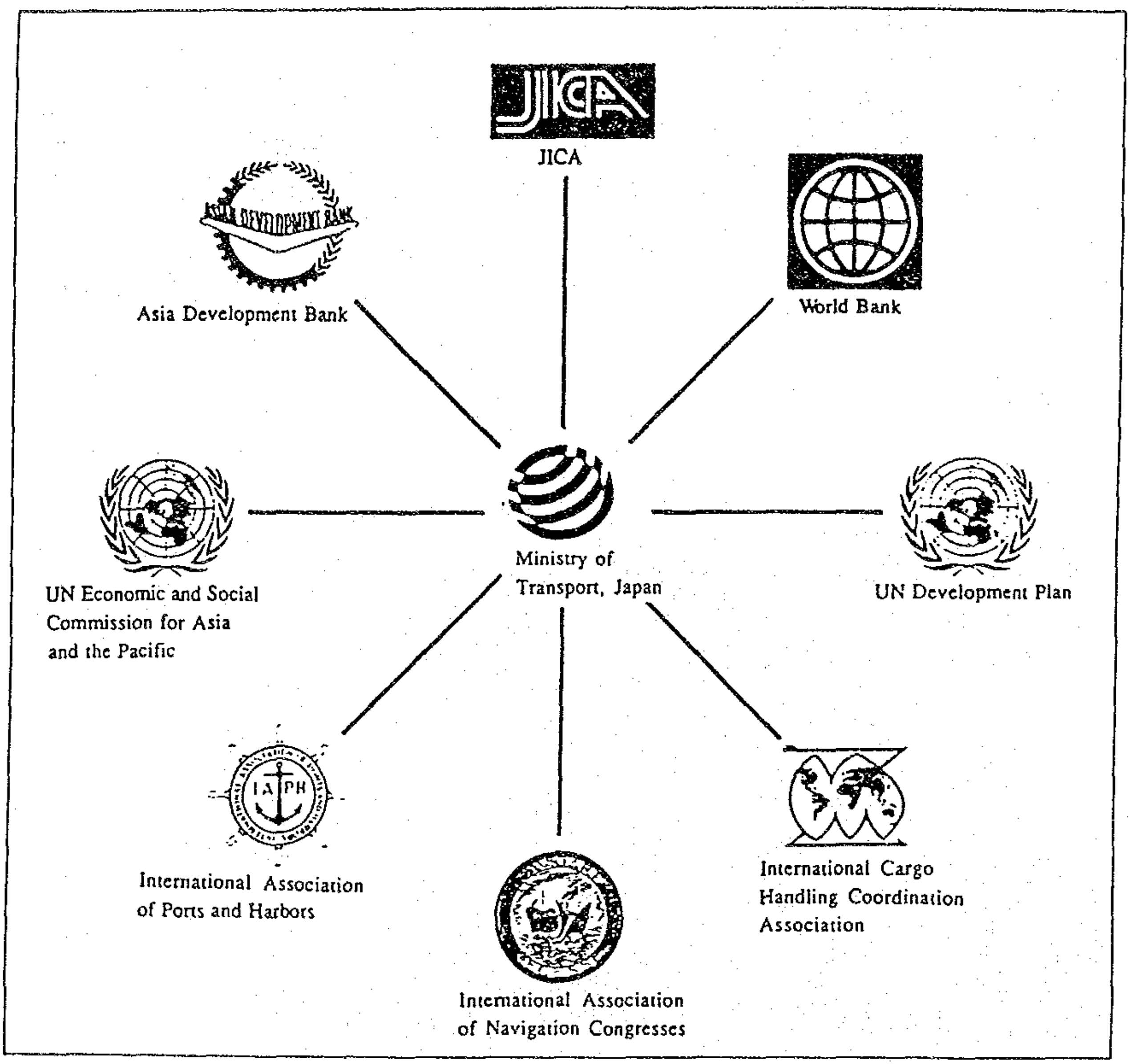


Example of Grant Aid Assistance - Port of Apia, Western Samoa



Example of Loan Assistance - Port of Colombo, Sri Lanka

II. STRENGTHENING OF MUTUAL COMPLEMENT FUNCTION OF TECHNICAL ASSISTANCE



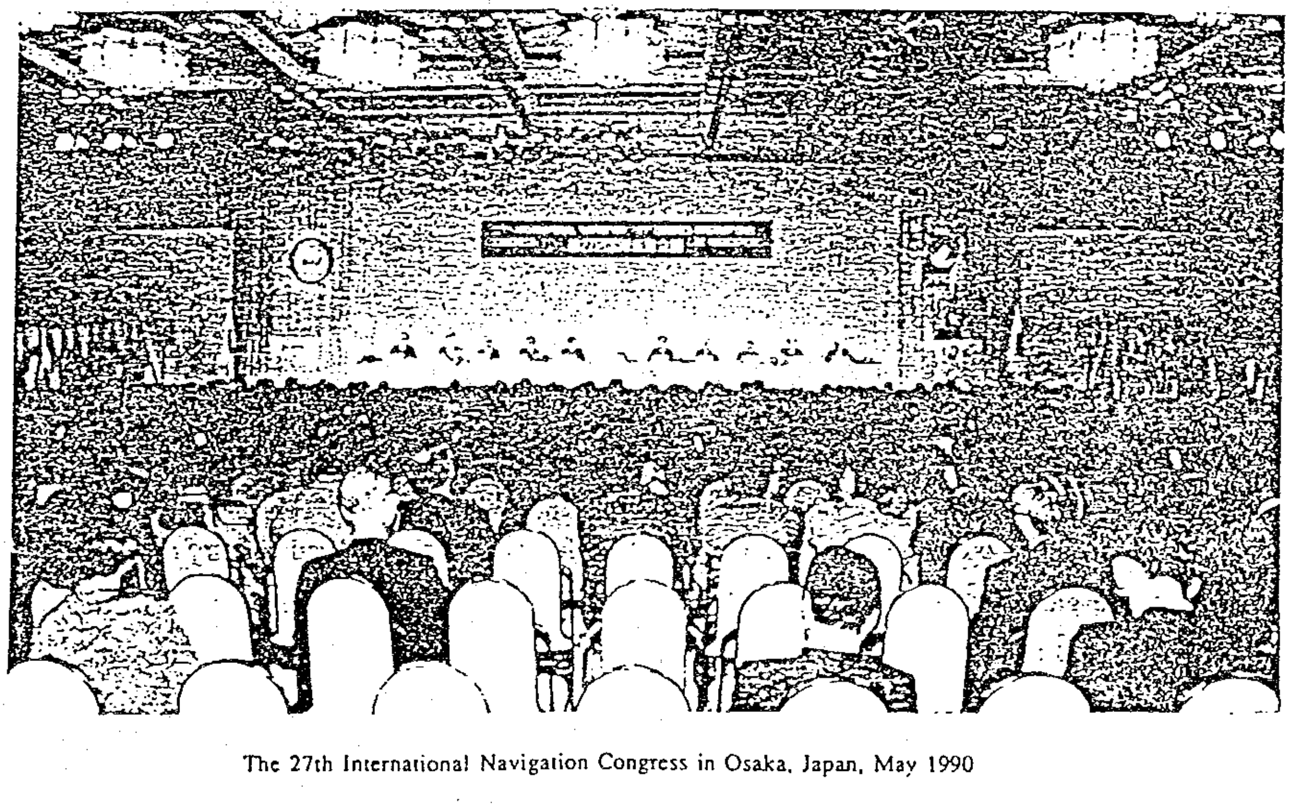
All the advanced countries should extend assistance to accelerate the self-supporting of developing ports in such a manner that the efforts of each advanced country can be fill up the gap. For this purpose, all the channels between international organizations, advanced countries and developing countries should be used for strengthening of the mutual complement function. Also, it is important to make the know how and the scientific and technical achievements of the advanced countries available more widely.

In this connection, Japan will promote the following measures in her international cooperation in the field of ports and harbours.

1. Cooperation with International Organizations

International Organizations on Ports and Harbours

International Association of Ports and Harbours (IAPH)	o An international organization mainly composed of port management bodies o The purpose is to develop and promote good relationship and cooperation among ports in the world and to exchange new technical information regarding development, organization, management and operation of ports. o The present membership is 385 from 84 countries.
International Association of Navigation Congresses (PIANC)	o Non-intergovernmental international organization to discuss technical problems regarding inland waterways, navigation and ports. o Composed of persons and organizations under the support of the participating Governments. o The present membership consists of 37 governments, 623 organizations and 1,855 persons.
International Cargo Handling Coordination Association (ICHCA)	o An international organization to make investigations and researches and exchange information to improve efficiency and economy regarding cargo handling and transportation. o Composed of organizations and persons concerned with cargo handling and port management. o The present membership consists of 895 organizations and 515 persons from 84 countries.



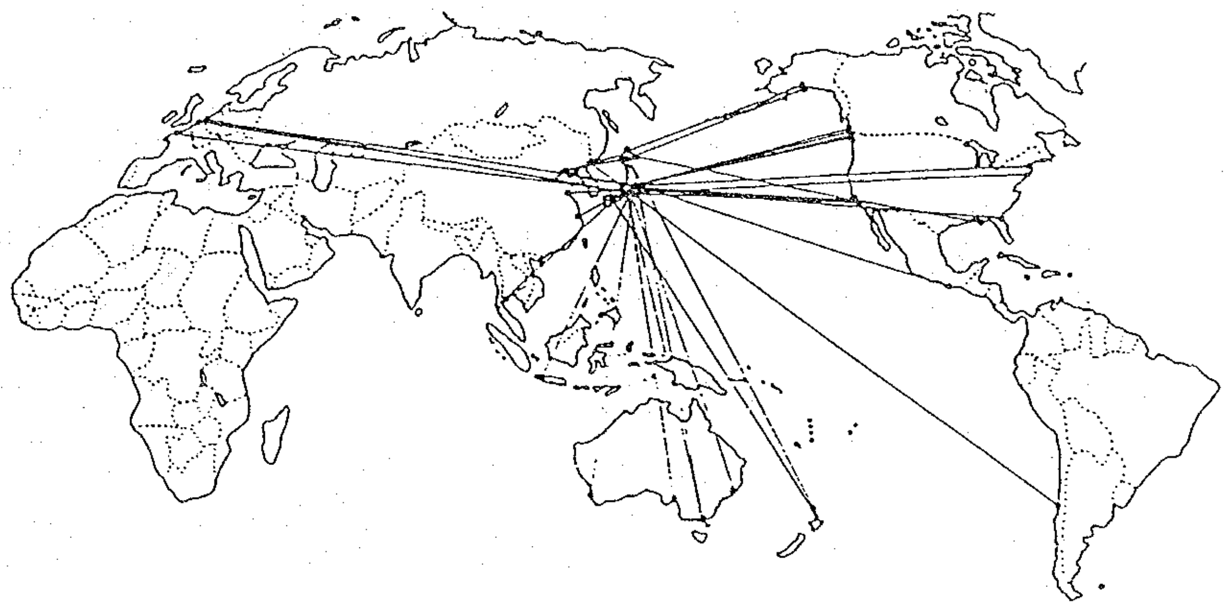
The 27th International Navigation Congress in Osaka, Japan, May 1990

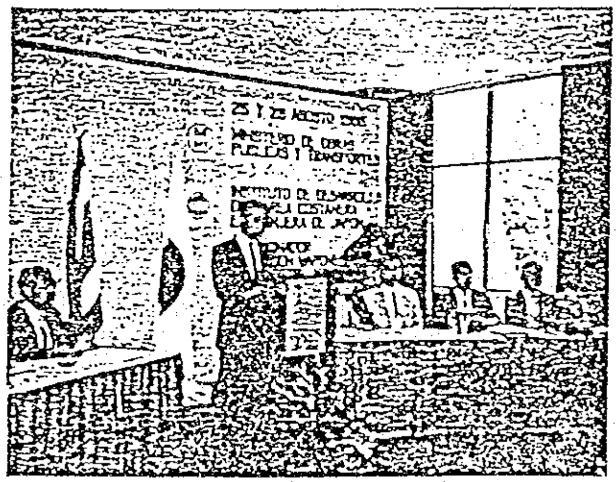
International organizations such as the Asia Development Bank (ADB), the World Bank (WB), the UN Economic and Social Commission for Asia and the Pacific (ESCAP), the UN Development Plan (UNDP) are playing an important role in international cooperation. We have promoted and will positively promote our cooperation with these organizations by personal participation and also promote joint programs with them.

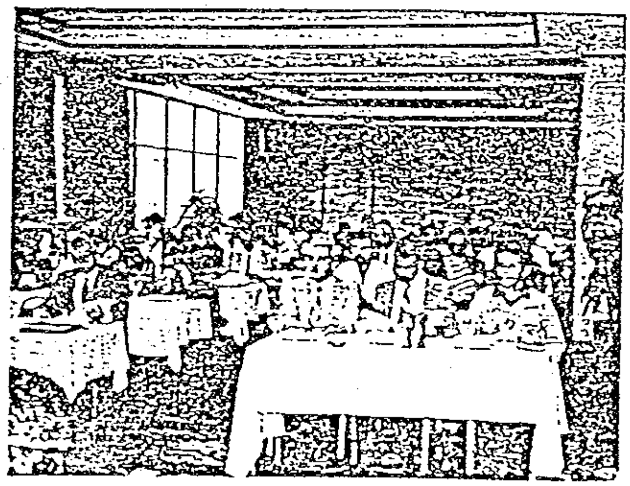
Also, we will continuously play a major role in international organizations on ports and harbours such as the International Association of Ports and Harbours (IAPH), the International Association of Navigation Congresses (PIANC), and the International Cargo Handling Coordination Association, and will try to transfer the know how of the advanced countries to the developing countries.

2. Support of Sister-Port Relationship and NGO's Cooperative Activities

Expanding of Sister-Port Networks





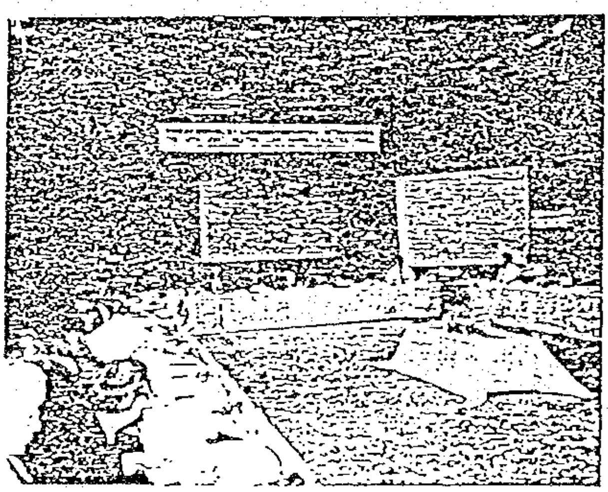


Port and Harbour Seminar held by The Overseas Coastal Area Development Institute of Japan (Held in Developing Countries every year)

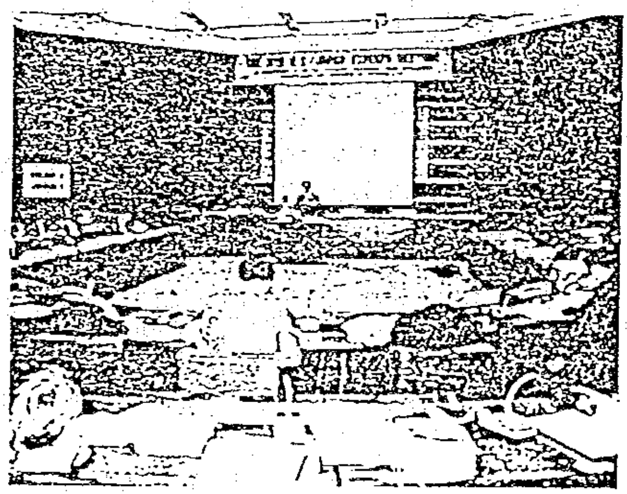
Along with rapid internationalization, international interchange not only at the national level but also at the local and private levels is getting widespread. In this connection, we will provide information services and counseling to support the sister-port activities made by port management bodies and NGO's activities.

3. Promoting Bilateral and Multilateral Information Exchange

Symposium on Port Development in Developing Countries



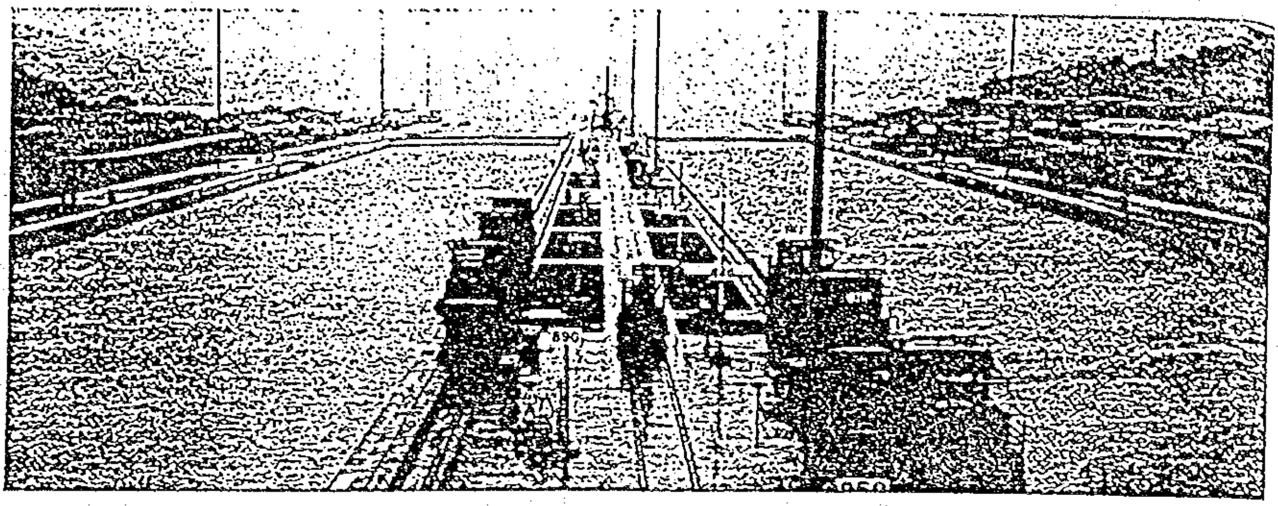
Japan-US Conference on Development and Utilization of Natural Resources



Japan-US Technical Conference on Treatment of Harmful Bottom Sediments

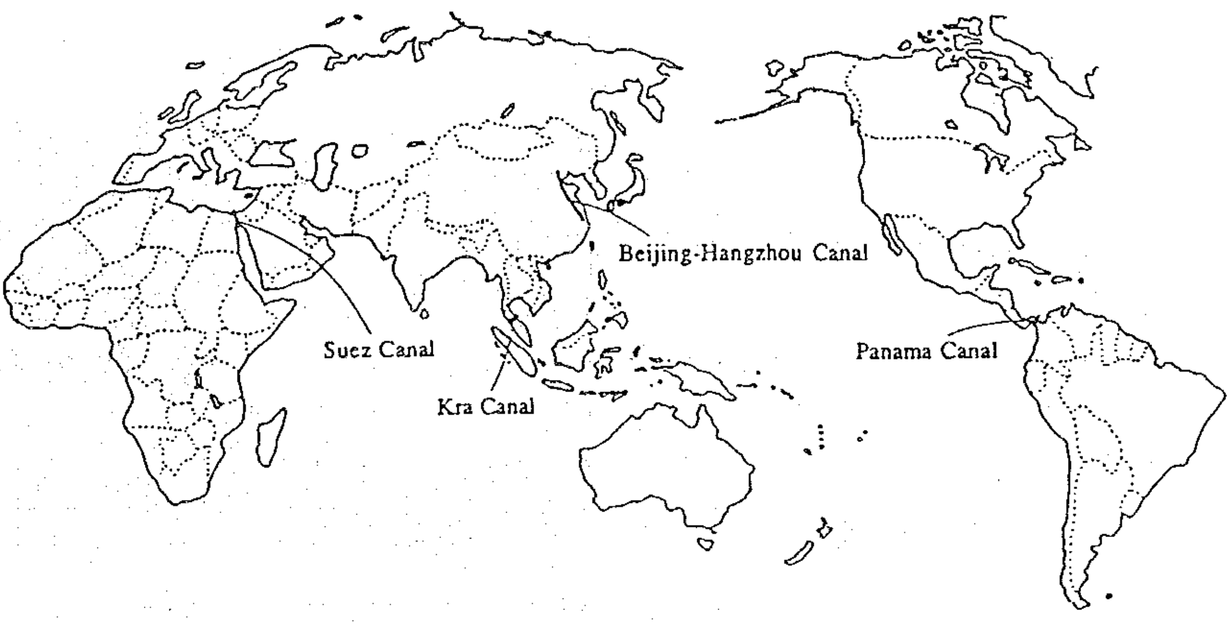
We will promote bilateral and multilateral information exchange to widen the access to the scientific and technical achievements, and also provide places of information exchange and dialog more frequently and continuously such as the symposiums and conferences as above.

4. Promoting Formulation of International Projects such as Global Super-Projects (GSP)



Panama Canal - Joint study on alternatives to the Panama Canal is now under way by Japan, USA and Panama.

Global Super-Projects (GSP)

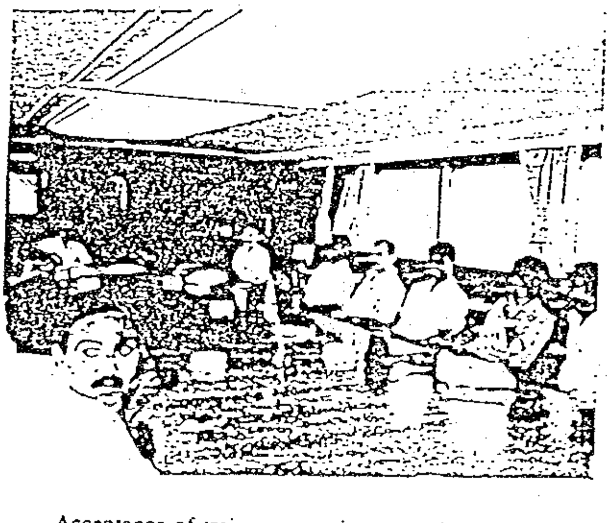


We will positively participate in the formulation and execution of big international projects that need global attendance, such as a global super-infrastructure and a global environment protection system.

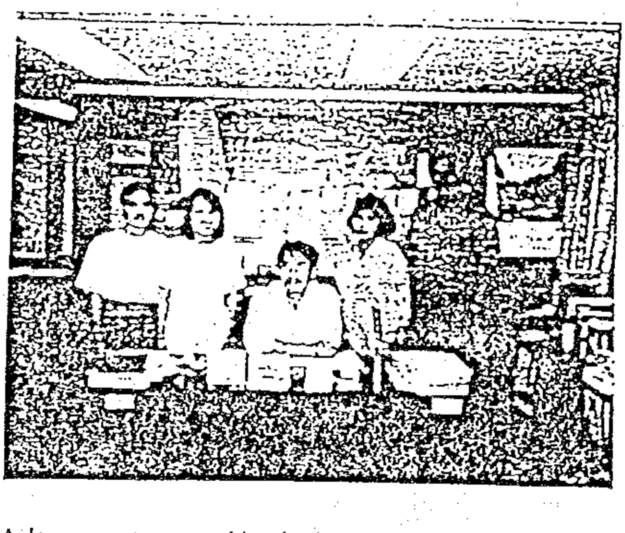
III. IMPROVEMENT AND STRENGTHENING OF JAPANESE SYSTEMS FOR INTERNATIONAL COOPERATION

Acceptance of trainees - training at Port and Harbour Research Institute

Acceptance of trainees - technical guidance of Port Management Body



Acceptance of trainees - touring around port aboard a ship



A Japanese expert working in the Philippines

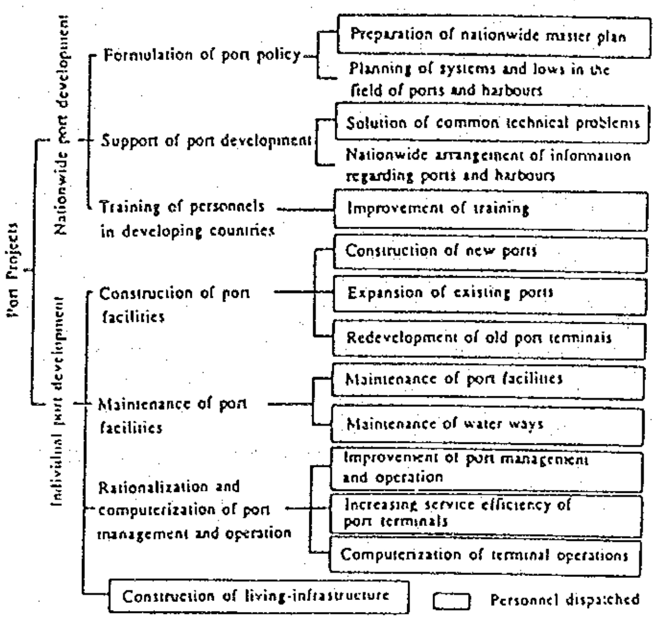
In order to render assistance smoothly and to obtain an expected result, it is necessary to train Japanese experts to acquire a high technical skills and an ability to adapt themselves to their assignments in developing countries, and also to provide workable systems there. Particularly in Japan, because the planning, construction and management of ports and harbours have been mainly undertaken by the State and local governments. The private sector's ability to render international cooperation is still insignificant, and lagging behind any of other advanced countries. Furthermore, unlike the international cooperation organizations in other countries, there are only a few experts being brought up as a specialist of international cooperation in individual technical fields even within foreign assistance organizations because of the Japanese employment system. On the other hand, Japan has advanced technology and unique experience under non-Western background. Accordingly, to promote our assistance more efficiently and effectively, we have to improve our ability to transfer our advanced technology and unique experience to developing countries. Therefore, we will promote the following measures to improve and strengthen our domestic systems for international cooperation.

1. Training Personnels and Improving Foreign Assignment Conditions for International Cooperation

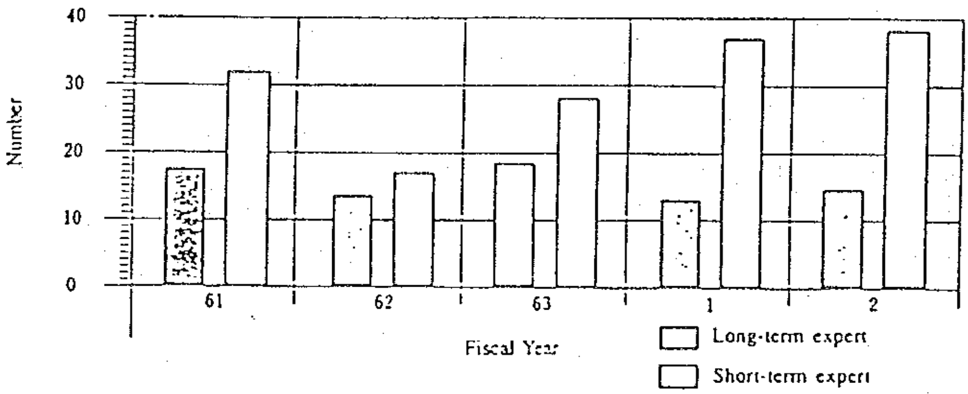
Personnel Training Program for International Cooperation in the Field of Ports and Harbours

Purpose	To train personnels to acquire enough knowledge necessary for international cooperation in the field of ports and harbours
Organizer	The Overseas Coastal Development Institute of Japan
Participants	Personnels of port management bodies and private companies
Subjects	1. Present situations of ports and harbours in developing countries (Port facilities and their utilization, port administrative system, etc.) 2. Management and operation of ports in developing countries 3. Present situation of ports and harbours in advanced countries 4. Case study on examples of international cooperation in the field of ports and harbours

Port Projects and Personnel Assignment



Number of Experts Dispatched Overseas in the Field of Ports and Harbours

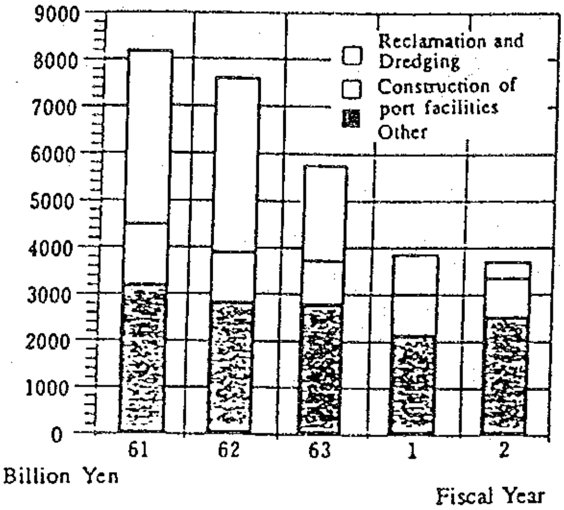


In order to obtain a sufficient number of able persons for overseas assignments, we will train those who are concerned with ports and harbours in Japan (personnel training program for international cooperation in the field of ports and harbours), and will use retired persons as well. Also, we will establish a manpower bank on such trainees, men of experience in overseas assignments, and those who have the skill or know how needed for international cooperation, and, thereupon, establish a system enabling the assignment of a number of such qualified persons effectively.

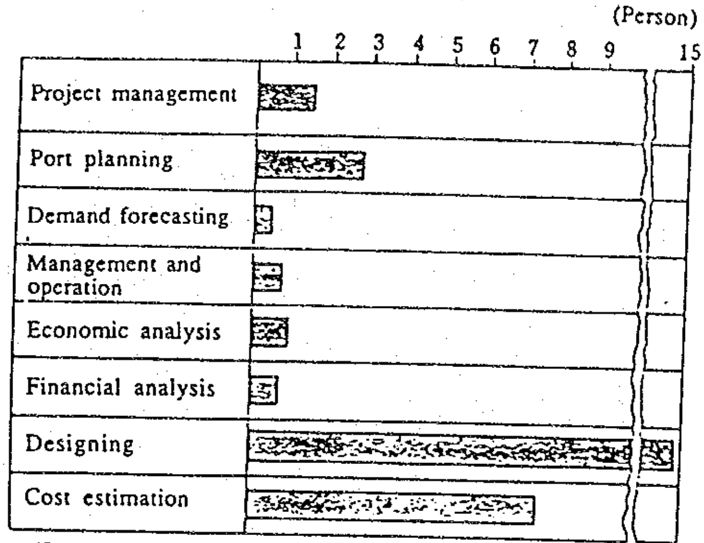
Further, it is necessary to establish a support system for such persons to work sufficiently on their assignment as experts in developing countries. In this regard, we will strengthen our backup structure, and study ways and means of extension of dispatch period and increasing of dispatch budget in order to make our assistance effective and continuous.

2. Improving of Private Enterprises's Ability

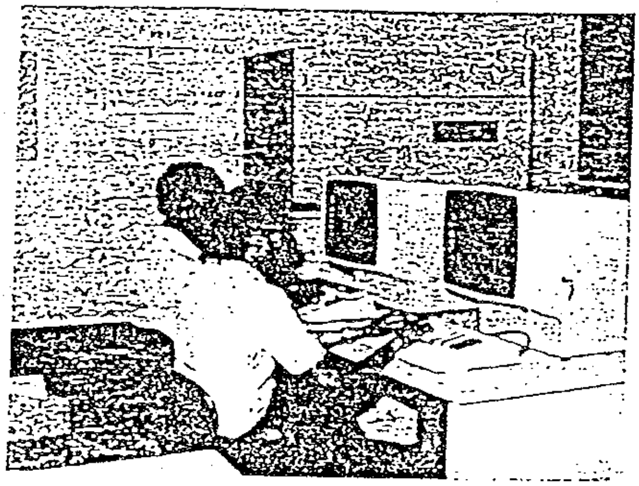
Port Construction Works done by Japanese Enterprises in Foreign Countries



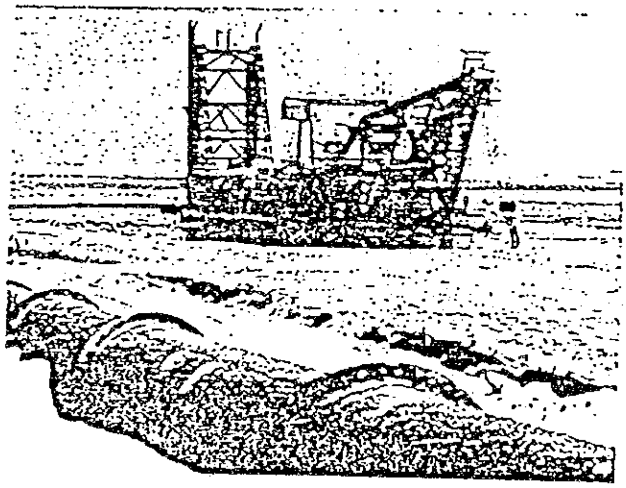
Number of Specialists for Foreign Assignments in the Field of Ports and Harbours
(Average Number of Persons per Private Consulting Company)



(Source : Ports and Harbours Bureau, Ministry of Transport)



Example of Technological Transfer by Japanese Company - Computerized Terminal Operation



Example of Port Construction Work by Japanese Company - Widening Project of the Suez Canal

Not only in the phase of bilateral assistance but also in the phase of multilateral assistance which is rendered mainly through an international financial institution, we consider it necessary to transfer our port and harbour technology through the private sector in order to make our assistance really effective. However, the number of consultants specializing in the field of port planning, management and operation is very small in Japan. So, it is important to improve the ability and expand the capacity of such consultants. Also, speaking of the Japanese port construction enterprises, their experience gained abroad is much smaller than that of other advanced countries. They are largely dependent upon the jobs offered from Japan relating to our foreign assistance programs. Accordingly, in order to make Japanese companies contribute more in the field of foreign assistance, we will endeavor to improve the business conditions by cultivating human resources, increasing the information collecting capability, forming a manpower network and developing technologies suitable for developing countries.

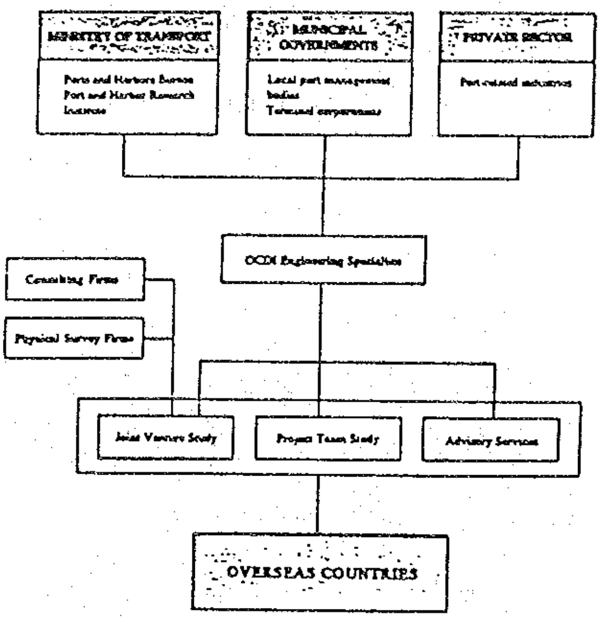
3. Improving Assistance Know How

Siltation in the Port of Banjarmasin, Indonesia

It is significant that Japan, as one of the technically advanced countries, transfers her advanced technologies to developing countries. However, it is not always appropriate that developing countries apply Japanese technologies without modifications for their internal situation. Developing countries have common problems such as siltation, environment assessment, and computerization of management and operation in their ports. Therefore, we will develop technologies applicable to developing countries by joint efforts of the administrative and private sectors.

4. Enhancing of Semi-Governmental Organizations

Role of The Overseas Coastal Area Development Institute of Japan



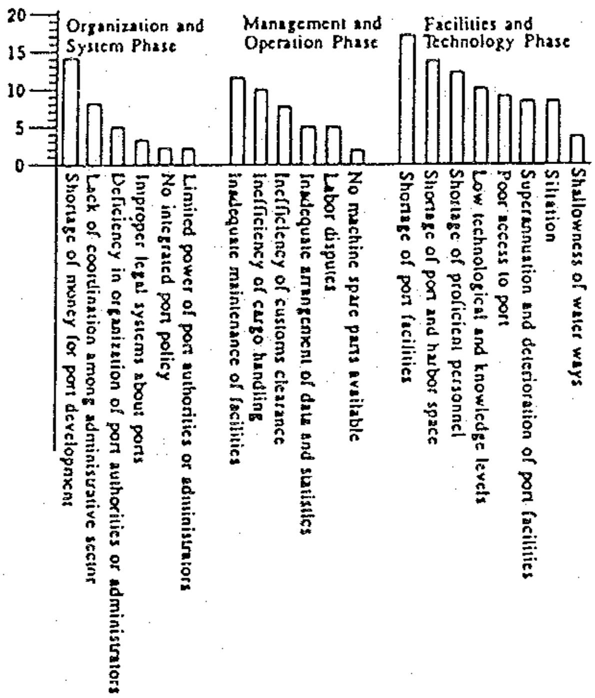
The role of the semi-governmental organization is increasingly important as an intermediary to effectively combine the administrative sector with the private one in regard to international cooperation. Realistically, the semi-governmental organization supports the project finding activities and information collecting activities which the private sector is making independently and transfers the port technologies which the administrative sector possesses exclusively to the private sector. The unique character which the semi-governmental organization inherently has the flexibility of the private sector, while maintaining its position as a public sector, must be utilized to a greater degree. As one of such semi-governmental organizations, The Overseas Coastal Area Development Institute of Japan was established in 1976. Since then, the Center has been working on technical cooperation in regard to the development and management in the waterfront area and ports. We will further strengthen and expand the Center's function.

5. Making Assistance Plans for Individual Country, Selecting and Executing Projects, and Improving Evaluation Systems

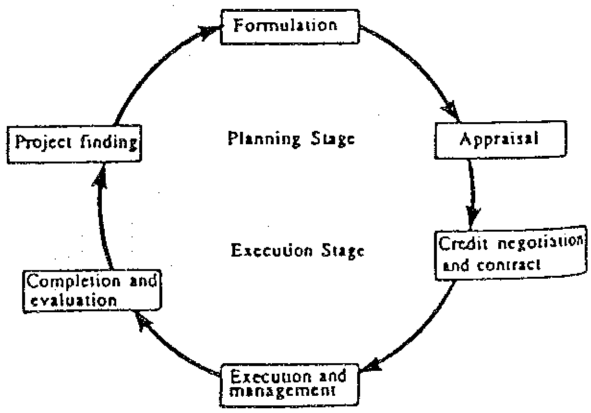
Development study team working abroad for technical cooperation

Investigation team working abroad for information collection

List of Problems in Developing Ports



Project Cycle



The port has a character of social-infrastructure in its locality as well as in the nation. And, it must be managed and operated by the people themselves living in that locality. Before rendering assistance, it is firstly necessary to analyze carefully any problems concerning ports and harbours, and secondly to make up a basis assistance policy from a specific as well as general point of view based on the socio-economic situation of the country concerned.

Furthermore, after the completion of assistance, it is necessary to see whether or not the executed project has achieved the set target, and whether or not it needs any modification depending on the subsequent development of the port. And it is also necessary to evaluate the project in order to make a better system for future cooperation.

Therefore, we will establish a solid system in each stage of project selection, execution and evaluation.

CHAPTER I-2

RECENT TECHNOLOGICAL TREND ON PORTS AND HARBOURS ENGINEERING IN JAPAN

1. PORT DEVELOPMENT POLICY

(1) Port Development Policy toward the 21st Century

In Japan ports and harbours , which constitute a large portion of the urban waterfront, have served mainly as distribution and industrial production centers, and therefore tended to emphasize profitability and efficiency. As a result, only these functions have expanded, resulting in the expulsion of other functions from the waterfront area. This has led to today's typical waterfront in Japan where single-function zone are arrenged in a parallel manner. As well, in many cities, port and harbour areas have became isolated from other urban areas, due to their lack of attractiveness.

To improve this situation and properly to meet the needs of a matured society, the Ministry of Transport devised in 1985, a long-term policy for the construction and improvement of ports and harbours, entitled 'Ports and Harbours toward the 21st Century.' This policy ensured that the first priority to 'the creation of a comprehensive port and harbour space 'be a plan aimed at creating a high-amenities port and harbour complex where a diversity of functions are integrated in a harmonious way. The focus of the plan was to recover the social functions of the area, thereby to develop an advanced and refreshing waterfront.

As Japanese sociaty becomes increasingly and information-oriented, the existing functions of ports and harbours will also be required to advance further and integrate a diversity of functions related to various types of services, business and research. Moreover, in order for port cities to progress with sustained vigor, it is important to make full use of the waterfront potential by providing a wide range of new roles. thus ports and harbours in Japan are expected to develop into a comprehensive waterfront space capable of meeting the needs of a matured sociaty and offering a refreshing environment to the citizens of the port cities.

The major points of this policy are described below;

- (1) Establishment of Advanced Distribution Space in Ports
  - ① Development of Comprehensive Distribution Terminals
  - ② Establishment of Port Distribution Information System
  - ③ Development of Port Freeway
  - ④ Development of Deep-Water Ports
  - ⑤ Increase of Navigation Safety

- (2) Development of High Quality Industrial Space
  - ① Development of High Technology Industrial Space
  - ② Development of Information Strategic Ports
  - ③ Port Development for Promoting Local Industries

- (3) Port Development for Daily Lives
  - ① Improvement of Port Amenity
  - ② Development of Ocean Recreation Bases
  - ③ Development of Earthquake Safe Ports
  - ④ Development of Waste Disposal Facilities in Ports

- (4) Promotion of Ocean Development and Utilization
  - ① Development of Artificial Offshore Islands
  - ② Development of Calm Areas in the Sea

(2) TOWARD AN ENRICHED WATERFRONT

In 1990, five years since it was first drawn up, measures proposed have already begun to take shape. The social and economic chenges surrounding ports and harbours have taken place beyond previous expectation, and preparations was made for new five-year plans which started in 1991 since the ongoing five-year plans for port and harbour development and coastal projects have entered their final year. Accordingly, measures proposed in 'The Ports and Harbours for the 21st Century' were reexamined while referring to the present situations, making considerations for necessary additions and further emphasis.

As a result, it was decided that it was appropriate to maintain the basic points of 'The Ports and Harbours for the 21st Century' as a long-term policy for port and harbour development. Considering the social and economic changes which have taken place since its compilation, however, additional emphasis is necessary on the following points.

- Qualitative Enhancement of a Comprehensive Port and Harbor Space
  - The Formation of an Easy-to-Use, Beautiful Port and Harbor Space
    - The formation of an easy-to-use port and harbor space
    - The formation of a beautiful port and harbor
  - Improvement of Functions in a Port and Harbor Space
    - The formation of an advanced distribution Space
    - The formation of a diversified and high-quality industrial space
    - The formation of an enriched living environment
  - The Preparation of a New Area for Port and Harbor Development
    - The redevelopoment of ports
    - The development of an offshore manmade island
- Contribution to Balanced National Development
  - The Promotion of Exchange throuth Improved Network
    - Systematic arrangement of ports
    - The intensification of mutual cooperation among ports
  - The Infrastructure Development for Integrated Local Settlement in Coastal Area
    - The infrastructure development for promotion of regional economy
    - The infrastructure development to counter urban problems
- Policy Measures to Realize an Enriched Waterfront

CONTENTS OF "AN ENRICHED WATERFRONT"

2. TECHNOLOGY OF PORTS AND HARBOURS

(1) Long-Term Policy for Technological Development of Ports and Harbours

Development of the port and harbour technology in japan has been mainly carried out by the State, but the technological faculties in private enterprises have also greatly developed. Since recently remarkable progress has been made in advanced technologies, outstanding leap of the technologies of ports and harbours could be possible by the use of advanced technologies.

In order to propel the technological development of ports and harbours powerfully under these circumstances, it is considered to be effective to clarify the targets of technological development and to obtain a nation wide understanding from the Japanese peaple by showing the promoting methods, which are conducted by the Ministry of Transport authorities, third sectors, and private enterprises respectively or cooperatively , or by showing how to support the development by the Mnistry of Transport.

Therefore, the Ports and Harbours Bureau of the Mnistry of Transport has formulated a policy necessary for facilitating the development of port and harbour technology of Japan toward the 21st century as 'Long-term Policy for Technological Development of Ports and Harbours'

On the other hand, motivated by enhancement of environment and resource energy problem in the global level the concept of 'Sustainable Development' has been proposed recently.

Further, with progress of the global and borderless economic activities, international communications and contributions to the world are required even in the area of ports and harbours technological development.

Thus, the following two ideas as principles have been set in order to promote technological development of ports and harbours.

1) Formation of waterfront which is mild to human beings and the earth.
2) International exchange of peaple and information. and contribution to the world.

Based on these principles, ten priority subjects in the field of technological development have been identified, such as "Creation of better environment of coastal area", Labour saving in port construction " and "Construction of highly efficient terminal and the like, and necessary means for promoting the technical development have also been shown.

In accordance with the longterm policy mentioned above, each of the compitent agencies and institute being engaged in technological development will facilitate technological development positively, making actual program concerning items, method, and timing of the technological development.

(2) Promotion measures for port technological development

In order to propel port technological development, Ports and harbours bureau, Ministry of Transport have prepared various kinds of measures to willingly support private sectors as well as is aggresively engaged in its own technological development.

1)Field proving test for new technology

It is of great importance for port facilities to secure safety because almost all of them are public facilities and in the case it is once destroyed a serious damage to human life, property and environment may be caused. Therefore, in order to put new technology into practice, a field proving test is inevitable to make sure of the execution performance and function of new technology in a construction site after the completion basic researches such as computation, model experiment and so on .

That's why Ministry of Transport facilitates a field proving test for new technology to put it into practice in an actual site.

2)Evaluation system for port technology of private enterprises

Ministry of Transport, as the compitent Minister offers new technological subjects needed to developments in the field of port facility improvement and evaluates the result of examination of the new technological systems applied by private enterprises, considering views of scholors and men of experience. By announcing the result of the evaluation, it becomes possible to spread the excellent technology and implement port facility improvement smoothly.

3)experiment area offering system in harbour area

Port construction works today has been implementing under severe natural conditions such as deep water, high wave and soft ground. It is inevitable for private enterprises to demonstrate their newly developped technology in the actual sea area, it being a big difficulty to find out a experiment area and coordinate parties concerned to demonstrate it.

Ports and habours bureau, Ministry of Transport has found out a system entitled the experiment area offering system in harbour area, which offers a experiment srea whwre private enterprises demonstrate their newly developped technology.

4)Collaboration system for technological development

The ability of technology in private enterprises has remarkably progressed through the accumulation of experience in port construction works. Therefore it is important to make the most of their ability to further develop the port technology, so a system has been utilized to shorten development period and enhance technological level, by which District port construction bureau and private enterprises cooperate to develop new technology and share the results of it among them.

On the other hand, Port and Harbour Research Institute has also been implementing the collaboration with private enterprises under the properly roll-sharing system.

5)subsidy financing and taxation system

Financing offered by the Ship and Ocean foundation, the Japan Shipbuilding industry foundation and Japan development bank is available for technolog development by private enterprises and public service corporations.

On the other hand favored treatment measures in trems of taxation are of great use for test &research expenditure by private enterprises and the collaboration with government owned institute furthermore, some extent of lower taxation system is also available for the purchase of computer utilized equipment to spread newly developped technology.

(3) .DEVELOPMENT OF DESIGN METHODS FOR PORT AND HARBOUR FACILITIES

In order to construct the port and harbour facilities safely and economically, we collect the latest information and data concernig design and construction of port facilities and we develop the rational·design methods. We write and edit the design standards,manuals and charts to spread the developed design method widely.

1) Development of design methods

(i) Several problems on design condition and method for the port facilities or the air port facilities

① Analysis of the lateral flow of steel structures on the soft ground

② Study on configuration and mechanical properties of the rubble mound

③ Study on the design methods of floating structures

④ Data-base system for the design and execution of high embankment in air ports

(ii) Investigation on the applicatin of the limit state design methods

(iii) Collection of design data on the existing port facilities

* dimensions of breakwaters, embankment and sea walls.
* disaster-striken port facilities.

2) Standardization of disign methods

(i) Study on standardization of disign methods for the port facilities

① Design and execution manuals on the dual cylinder caisson type breakwater and the sand-mound banks. (Fig.-1)

② Study on improvement of the technical standards on port roads

③ Investigation on restructuring of the existing mooring facilities

(ii) Investigatin on the maintenance standards of waterfront bridges

(iii) Investigation for the materials and the maintenance technology of attached facilities on the amenity-oriented facilities

* Investigation on the facilities in marina, fishing park and green park .

(4) AUTOMATIC DESIGN OF PORT AND HARBOUR FACILITIES

We must design the facilities in accordance with changes of natural conditions so as to construct them safely and economically. For the ratinalization of design, standardization of design method and automatization of design by means of computer are indispensable subjects. Now we are developing automatic design systems and optimum design system for port and harbour facilities .

1) Development of Automatic Design Programs

(i) Basic design program of a steel sheet-pile cellular cofferdam

(ii) Improvement of the existing programs

① Basic design program of a L-shaped block type quaywall

② Bar arrangement drawing program of a caisson (Fig.-2)

③ Translation to the personal computer programs

* stability caluculation of a caisson type structure

* vertical steel piled pier

* basic design for a open-type pier

(5) SYSTEM DESIGN OF PORTS AND HARBOUR FACILITIES

Nowadays,due to varying functions of a port, some projects are carried out in order to create comprehensive space in ports.

Components of ports, for example, water areas ,wharves, roads,business and amenity districts have to peform their roles adequately, in order to compose the best space of ports in view of safety, efficiency and amenity. We reseach the methodology of planning for functions, scale and allocation of facilities which are important for port-system to perform best.

1) Study on the marine traffic and ship maneuverability for the port planning

(i) Observation and analysis for the marine traffic

* tokyo bay-mouth,

(ii) Study on the estimation method of the port planning with the ship maneuvering simmulation (Fig.-3)

(iii) Development of planning methods on the port facilities for the Techno-Super-Linner (Fig.-5)

2) System design of the port space

(i) Investigation on the cargo hundling system in containner wharves

* Ooi containner wharves in Tokyo ,Hakozaki in Hakata

(6) COMPREHENSIVE STUDY ON PORT DEVELOPMENT

With the progress of social and economic maturity, citizen's consciousness toward port development become diversified. Planner are requested to be careful about what is going on in the respective areas and should have analytical methodologies which are needed in the planning stage.

1) Study on road transportation planning in port area

(i) Study on methods for forcasting traffic volume

2) Cargo transportation

(i) Study on transportation of high value added cargo

(ii) Study on foreign trade container wharves which spread to the local areas

① Container cargo distribution in Tohoku district

3) Study on high utilization of port space

(i) Study on systemizing port space planning method

* Collection of redevelopment data in the foreign ports

(ii) Systemizing portscape planning

(iii) Investigation on the urban cable vehicle system in port areas (Fig.-4)

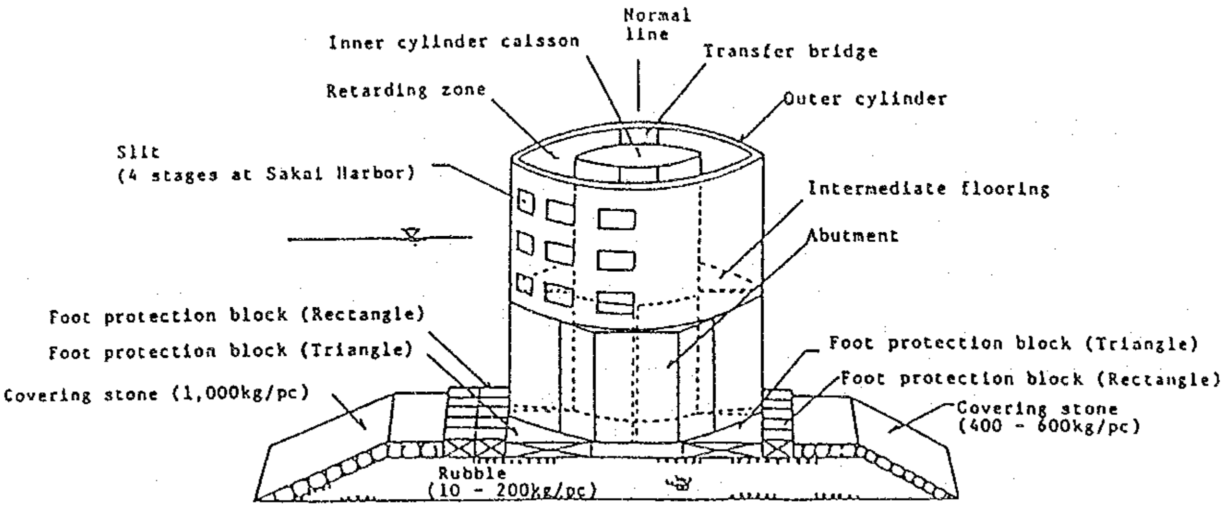


Fig. − 1 . Example of dual cylinder caisson

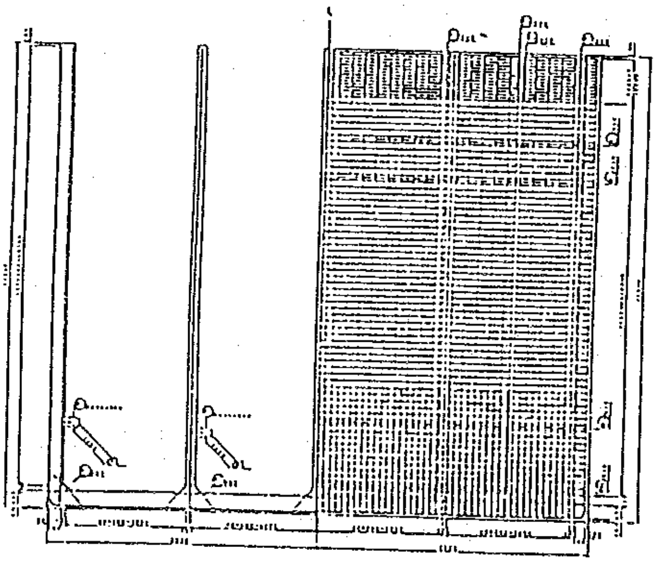
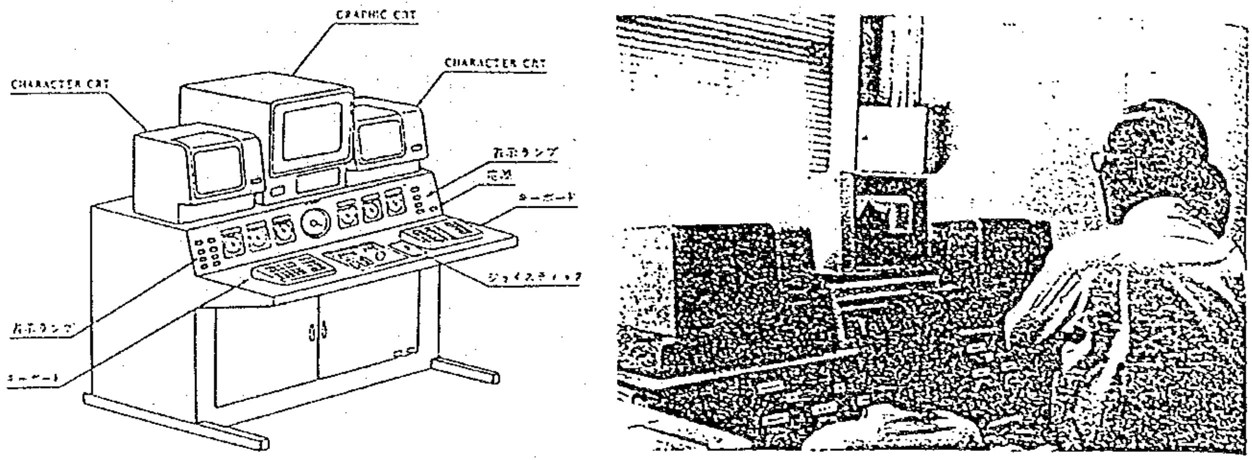


Fig. − 2 . Bar arrangement drawing of caisson

by automatic drafting machine



Fig－3. Ship maneuvering simmulator

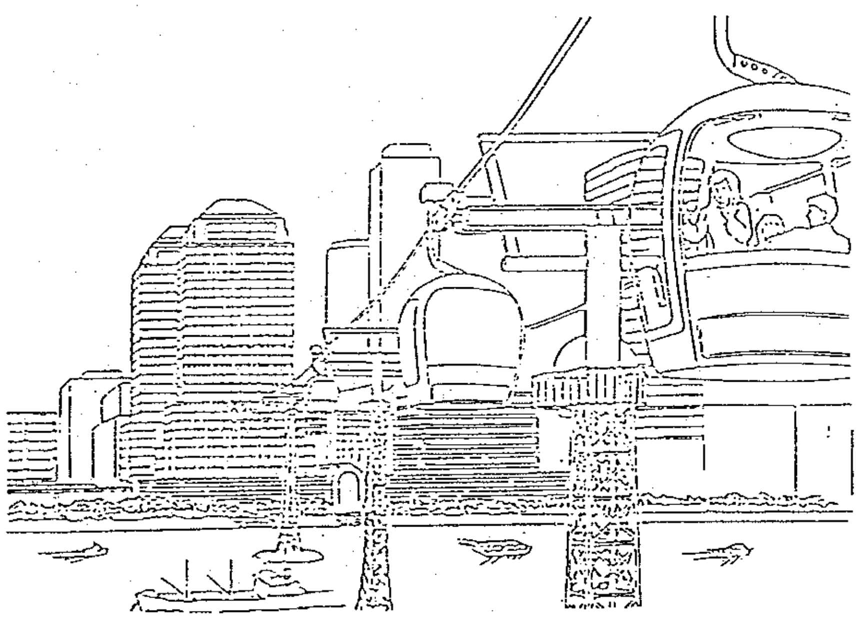


Fig.－4　Idea of a urban cable vehicle

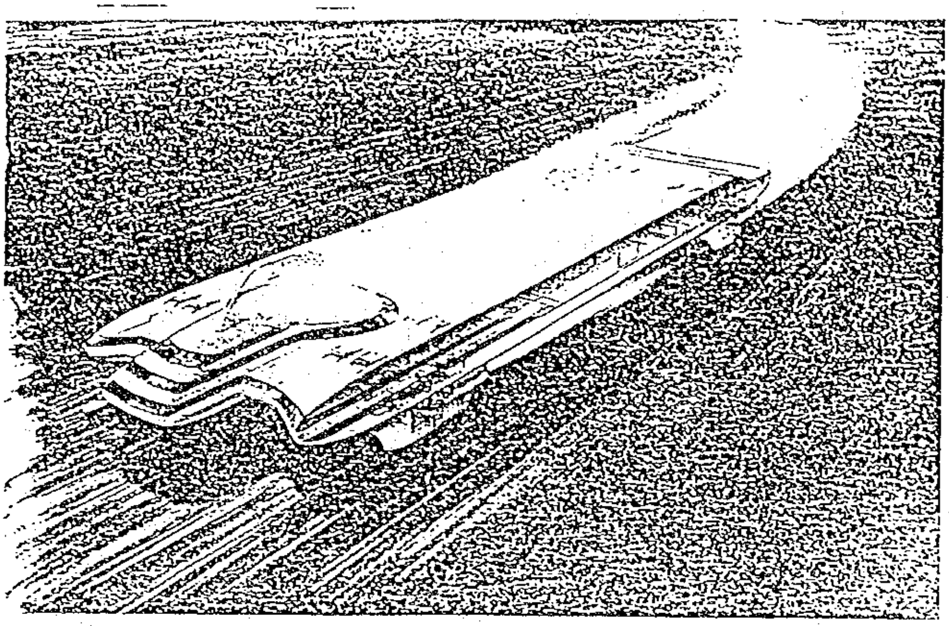


Fig. 5. Image of Ultra-high-speed vessels, such as Techno-Superliner

*ship speed : 50 knots (93 km/h)

*payload capacity : 1,000 metric tons

*cruise distance : 500 nautical miles (930 km)

*ocean waves : 4.5～6.0 m

(7) Main Technical Developments

Main recent technical developments include the development and testing of a deep water structure, development of automated deep water work techniques using robots, development of high accuracy sensors, and improvement of a navigation simulator for planning safe water areas. These developments are generally carried out jointly by the national government, academic and private sectors using the technical capacity of the private sector.

1) Wave power extracting caisson break water

Provided with air rooms on its front, this type of breakwater converts wave energy into air flow to reduce wave force acting on itself. It has also a superb wave reducing function.

In addition as wave energy is converted into air flow with this type of breakwater, the air flow can be used to rotate electrical generator's turbine. The Ports and Harbours Bureau is planning a power generation test on the site of water breaking rest of actual scale to be conducted at an outer harbour area. Field observation in Sakata Port is underway.

2) Double cylinder caisson

Using cylindrical structure, member strength can easily be secured with this type of breakwater. This saves material used, reduces weight and simplifies structural configuration, reducing manufacturing term consequently. Since wave force is imposed out of phase, its resultant gets smaller. As a typical breakwater construction for a large depth, this design is being studied.

Model tests and carried out to establish design procedures.

Three units of breakwater of this type have been installed at Sakai Minato, and a field test has begun to measure member stress and wave pressure.

3) Water-affinity breakwater

With the vertical slit caisson used for the breakwater main body, the breakwater was furnished with a wave dissipating function. At the portion on the harbour side, the breakwater crown was made as low as possible so that people could easily approach the water. The superstructure was erected as a step from the sea side nearly up to the middle of the structure, and the horizontal top fabricated into a projecting double-deck construction, whereby a broad space was made available for people to gather and stroll. Citizens can command a view from the upper deck over both the sea and harbour sides. The upper deck functions as a shield from the sun, wave and wind. Steps between the upper and lower decks are provided every 100m.

This breakwater will be constructed at Wakayama Marina City.

4) Moundless beakwater with wide footing on soft ground

Employed for soft ground, this type of breakwater utilizes cohesion for resistance to wave force, and, also, lateral resistance of piles on which pier body is fixed. This reduces pier weight and eliminates necessity of ground amendment.

Analysis of observation results is being carried out, and the first practice is now under construction in Kumamoto Port.

5) Large caisson installation method at very deep water

Large caisson installation technique is vital for construction of a very deep breakwater and bulk head. More to say, caissons for large depth are frequently of shapes different from the conventional rectangle. Techniques should be refined for their manufacturing, launching and installation. Water charging and discharging technique and rapid filling technique will be investigated on the planned installation of trapezoidal caissons for breakwater at the mouth of Kamaishi Bay.

6) Mechanized rubble levelling

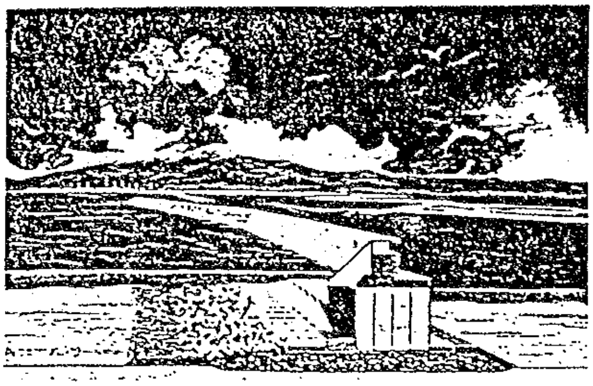
Many breakwater and revetment designs in Japan are of the gravity type, representative of which is the caisson type breakwater. In the construction of a caisson type breakwater, a rubble mound on which the caisson is installed must be built with its top levelled flat.

In general, rubble levelling is manually performed by divers. As working depth increases, however, a strong need arises for the application of machines to increase work efficiency and ensure safety. Currently, a number of rubble levellers are being put into practical operation.

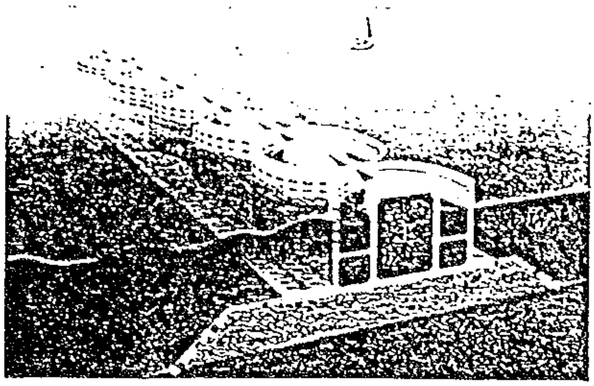
7) Underwater survey robot

Demand for robotization of execution is increasing to cope with deepening of work sites in harbour construction. For the time being, the Ports and Harbours Bureau is pushing forward the development of an underwater survey robot. Its main specifications:① working conditions (depth:50m, tidal current:1 knot), ② walking performance (speed of straight walk:5 to 10m/min, rate of rotation:420 deg/min, permissible ground unevenness: ±35cm and climbable slope:27 deg). A test has already been conducted for an underwater machine in actual field.

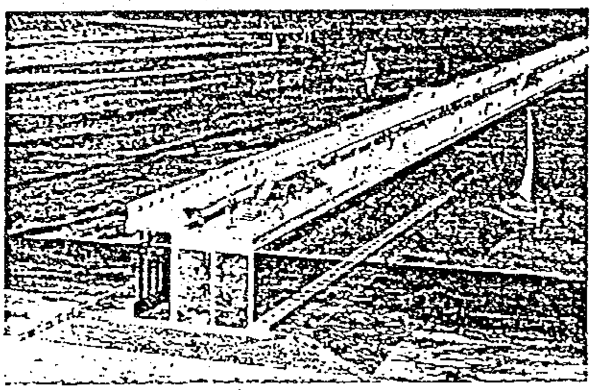
The next target being weight reduction, its early practice is desired.



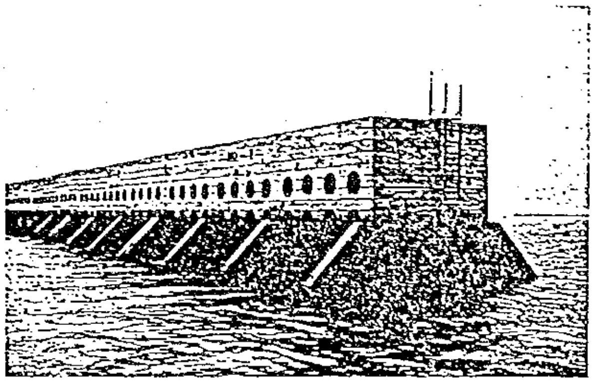
Wave power extrading caisson breakwater



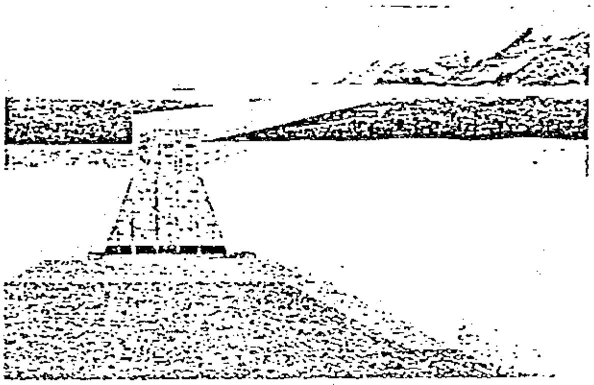
Double cylinder caisson



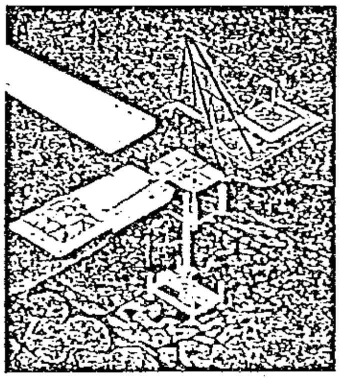
Water-affinity breakwater



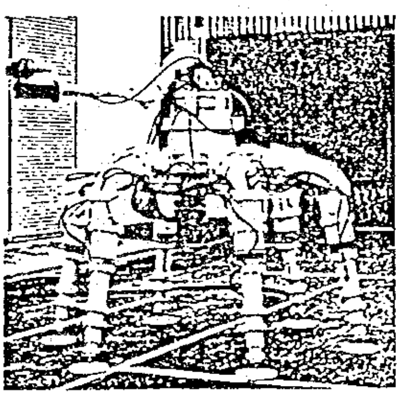
Moundless breakwater with wide footing on soft ground



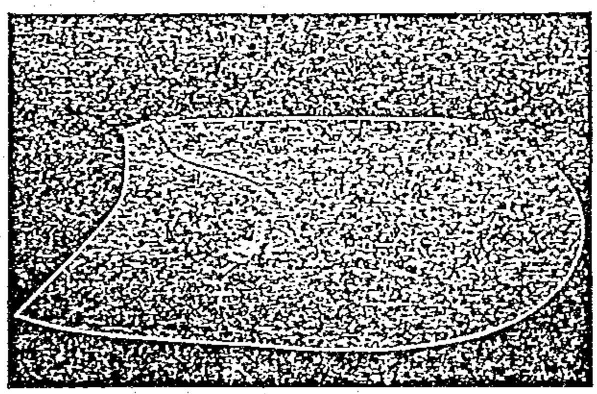
Large caisson installation method at very deep water



Mechanized rubble levelling



Underwater survey robot



Construction technique in consideration of environment

Technology of Ports and Harbours

CHAPTER 2 : ENVIRONMENTAL PRESERVATION AND COASTAL DEVELOPMENT

ENVIRONMENTAL PRESERVATION AND COASTAL DEVELOPMENT

Port and Harbour Research Institute,
Ministry of Transport

JAPAN INTERNATIONAL COOPERATION AGENCY

Contents

1 Introduction 1
- 1.1 Why Environmental Preservation? 1
- 1.2 What is Environmental Hazard? 1
  - 1.2.1 Sediments 1
  - 1.2.2 Organic Matter 2
  - 1.2.3 Chemicals 3
  - 1.2.4 Insecticides and Herbicides 3
  - 1.2.5 Oils 3
  - 1.2.6 Radionuclides 3
  - 1.2.7 Thermal Pollution 3
  - 1.2.8 General Rubbish 4
- 1.3 What are WQM, WQS, and Assessment? 4
  - 1.3.1 The Concept of the Water Quality Management 4
  - 1.3.2 The Concept of Water Quality Standards 4
  - 1.3.3 Assessment 5

2 Summary of Marine Environment Preservation Work in Japan 6
- 2.1 Water Pollution problems in Japan 6
  - 2.1.1 Before 1950s 6
  - 2.1.2 1950s 6
  - 2.1.3 1960s 6
  - 2.1.4 1970s 6
  - 2.1.5 1980s 7
  - 2.1.6 Summary 7
- 2.2 Establishment of Water Quality Wtandards 7
  - 2.2.1 Establishment of WQS 7
  - 2.2.2 Criteria for the Standards 8
  - 2.2.3 Water Pollution Control Law 8
- 2.3 Outline of Marine Environment Improvement Work 8

3 Environmental Impact Assessment 10
- 3.1 Promotion of Environmental Impact Assessment 10
  - 3.1.1 Environmental Impact Assessment 10
  - 3.1.2 Implementation Scheme 10
  - 3.1.3 Technical Background 10
- 3.2 Methods of Assessing Environmental Impact 11
  - 3.2.1 Mass Balance Method 11
  - 3.2.2 Techniques for Assessment 12
- 3.3 Hydraulic Experiment 13
  - 3.3.1 Equipments 13
  - 3.3.2 Similarity Law 14
- 3.4 Numeric Simulation 14
  - 3.4.1 Governing Equations 14

3.4.2 Finite Difference Method 15
3.4.3 Tidal Current Model 17
3.4.4 Substance Diffusion Model 19
3.4.5 Water Quality Model 19

4 Case Studies 21
4.1 Surface Flow and Particle Settling in a Coastal Reed Field 21
4.2 New Idea on Waterfront Development Harmonic Design for Space Utilization and Water Quality Improvement 22

List of Tables

1 A History of Japanese Efforts to Preserve Water Quality 23
2 Environmental Water Quality Standards 24
3 Environmental Water Quality Standards 24
4 b. Lakes 25
5 c. Nitrogen and phosphorus in lakes and reservoirs 25
6 d. Coastal waters 25
7 Outline of the Ports and Marine Environment Implrovement Work 26
8 Comparisons between techniques for assessment 27
9 Scale ratios of hydraulic model 27
10 List of Discretization 28

1 Introduction

1.1 Why Environmental Preservation?

Due to population pressure and the onset of industrialization to the coastal area, a number of developing countries is today experiencing serious environmental degradation in terms both of depletion of natural resources and pollution.

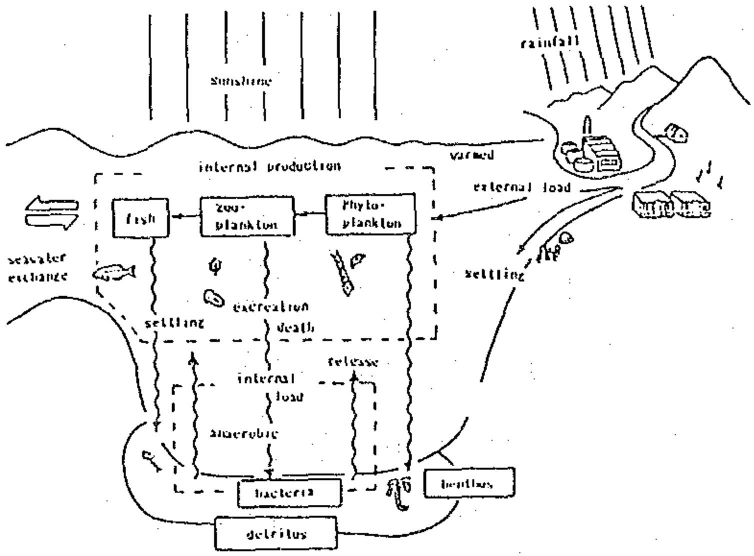


Fig. 1 Schematic image of a coastal line

The impact of such environmental degradation is felt most severely at local and regional levels.

Developing countries experiencing serious environmental degradation should, therefore, give priority attention to preparing and implementing regional and local level development plans that systematically provide for the improvement of their environmental situation, along with immediate and sustained improvements in levels of living in the concerned areas.

1.2 What is Environmental Hazard?

Various environmental hazards can be conveniently grouped under seven headings, namely: sediment; organic matter; chemicals; herbicides and insecticides; oils; radionuclides; heat and general rubbish.

1.2.1 Sediments

Natural sediment loads from a river can often be high, but in general they are restricted to periods following large storms. Harbour works, dredging, and other such maritime construction can disturb silt and produce detrimental effects. Light penetration and photosynthetic activity are reduced. Bottom dwelling animals and plants are smothered, fish spawning is impaired. The waste assimilation capacity of the water is reduced. And shellfish, particularly oysters, clog up and may die.

1.2.2 Organic Matter

This is the most common type of pollution and its effect is largely indirect. The organic matter circulates in a complicated network system (Fig.–2). Once the balance is disturbed by an impact, some problems are brought to light.

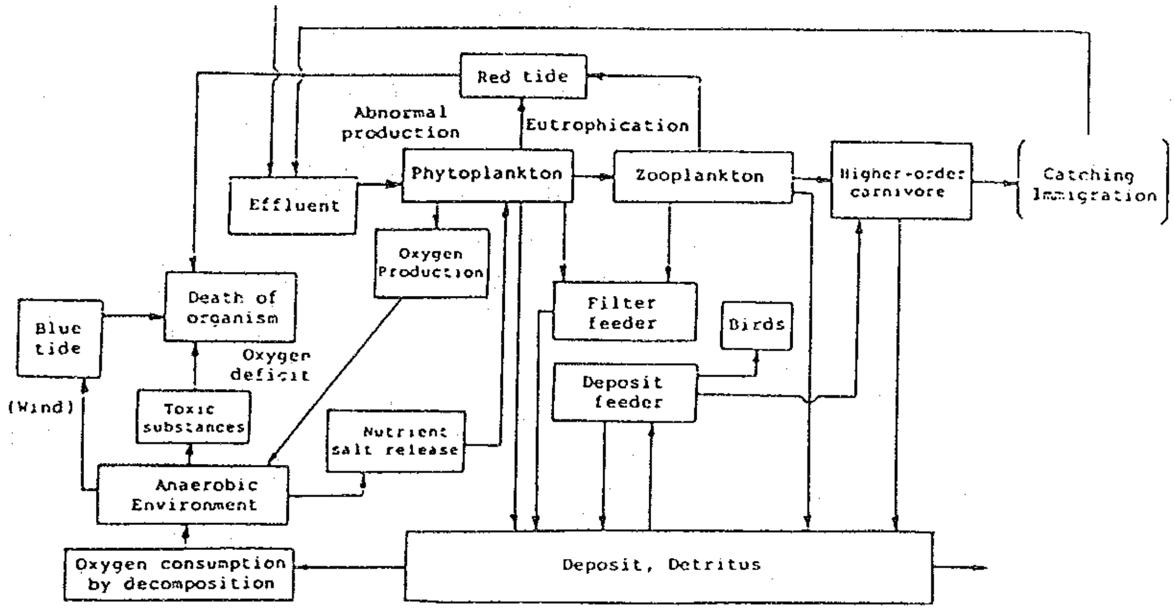


Fig. 2 Organic Matter in a Coastal Area

Eutrophication (*Red Tide*), and low dissolved oxygen levels in estuaries (*Blue Tide*) are two major manifestations of this problem.

Red Tide is mainly derived by organic enrichment arising from city sewage disposal. A number of plankton is increased rapidly by enriched organic matter, interaction of living creatures, and decrease of restriction from the other plankton. The accumulation of the plankton consumes dissolved oxygen and contains toxin in itself. According to these effects, coastal creatures and cultured fish are damaged in large area.

Blue tide is mainly derived by oxygen–deficient water mass. In the stratified water, short supply of oxygen in lower layer is occur. Because, the consuming speed of oxygen by organism's decomposition over the supplying speed of oxygen by surface layer. The oxygen–deficient water mass lied lower layer as a dragging pit. When the water mass is disturbed by wind driven current, the oxygen–deficient water mass comes up to surface layer. It caused damage for coastal creatures and cultured fish. The blue color comes from sulfur that is reduced from the sea bottom.

1.2.3 Chemicals

Chemical pollution causes direct damage because poisons are involved. The substances vary as much as the industry varies: phenol, cyanides, arsenic, chlorine, slaked lime and compounds of many heavy metals. Poisonous chemicals can directly cause fish kills. Paint remover tipped into a salmon or trout stream can kill all the fish there. The only way to treat such poisonous residues are dilution to the point where they become harmless.

Heavy metals are particularly harmful. Oysters and cockles can accumulate heavy metals, such as mercury or cadmium, and concentrate them in their bodies until they become dangerous as food. Certain fish also accumulate heavy metals and can cause Minamata disease in humans who eat them.

1.2.4 Insecticides and Herbicides

Seabirds can accumulate high concentrations of persistent insecticides such as DDT. The insecticide residue becomes ever more concentrated as it progresses up the food chain. The sea birds then lay easily broken, thin–shelled, eggs and so fail to reproduce. In addition DDT and other chlorinated hydrocarbons, such as endrin, aldrin and dieldrin, are extremely toxic to fish. Heavy fish kills can follow crop spraying if some of the spray is blown into the water.

1.2.5 Oils

Oils pollution is mainly caused by dumping a tank washing water of an oil tanker and oil spilling of an accident. For maintenance of the first case, each port authority and private companies construct oil disposing facilities. But, oil pollution problem still occupies a main cause of marine pollution.

After spilling out of the oil, oil begins to change. The spill spreads and starts to evaporate. Oil droplets disperse into the water column, a generic liquid core sample. Some of the oil's aromatic components dissolve, and the slick grows more viscous. As waves stir, it forms a heavy water-in-oil emulsion, or mousse, almost impossible fro cleanup crews to pump. Eventually wind and waves shear the mousse into pancakes, which in turn break into tar balls that may wash ashore.

1.2.6 Radionuclides

The present situation about radioactive pollution is reassuring. The nuclear industry prides itself on the protection standards that were adopted before the technology became widespread. However, public concern is still lively and any possible radioactivity needs to be scrupulously investigated and meticulously documented in any environmental assessment.

1.2.7 Thermal Pollution

Hot water is a pollutant because it contains far less dissolved oxygen then water at lower temperatures; also because, at temperatures above about 37deg–C, the number of plants and animals able to tolerate the heat rapidly diminish. Above 42deg–C very few can live.

In temperate climates it seems that the effect of heated water, released by the cooling towers of electricity generators, has been beneficial to estuarine ecosystems. It has the impact of an earlier and longer-lasting summer growth period. But the situation is different in hotter climates. On the South-eastern coasts of the U.S. and in the Gulf of Mexico, summer temperatures are already near the upper limit of tolerance for much marine life.

1.2.8 General Rubbish

The wholesale dumping of rubbish in water bodies is one of the uglier features of the modern environment. It is made worse by the greater mobility of societies today, which allows people to visit even remote beauty spots in large numbers. Where public spirit is wanting, they will leave their rubbish behind them.

1.3 What are WQM, WQS, and Assessment?

1.3.1 The Concept of the Water Quality Management

To prevents environmental hazard, we need a strategy of Water Quality Management (WQM). It means not only provide typical single case by case but also create general concepts of managing entire environmental systems.
In principle they should contain:

- a clear identification of the environmental "issues"
- a conceptual model of the main processes
- the environmental objectives and criteria
- a program of measurement

1.3.2 The Concept of Water Quality Standards

To clarifies the environmental objectives and it's criteria, Water Quality Standards (WQS) are need to enact. WQS are established by two major objects. One is related to the human health and the other one is related to the quality of life. The later one is includes wild life preservation and total ecological systems.
In principle WQS should refer to:

- "desirable levels"
- Goals of water management and targets for pollution control authorities
- evaluation of the effectiveness of regulatory measures
- relationship to the effluent standards
- assessment of the present status
- pollution control programs

1.3.3 Assessment

Environmental assessment is a prelude to environmental management. The piece of coast to be managed may be under actual pressure such as eutrophication, pollution or overcrouwding, or it may be under threat of pressure from some proposed development. To ensure that this later possibility is properly considered, many states have enacted environmental impact legislation. This type of law places a legal requirement on a developer to assess the environment to create and maintain conditions under which man and nature can exist in productive harmony.

In principle the strategy for assessment should mention:

- well-defined objectives
- analysis
- coordination
- leadership

2 Summary of Marine Environment Preservation Work in Japan

2.1 Water Pollution problems in Japan

2.1.1 Before 1950s

Although it is likely that the problem of water pollution in Japan began before industrial modernization (1870s), the first case of water pollution affecting human life was recorded in the years of Meiji Period (1867–1911). This occurred as a result of spillage of pit water from the Asio Copper Mine into the Waterase River damaging riverside paddy rice. With the growth of industry, there has been a subsequent gradual increase in waste water giving risk to the problems of pollution in various parts of Japan.

2.1.2 1950s

During the period of industrial reconstruction after WW II, There was disputes concerning problems arising from water pollution causing great damage to river fisheries. One of these fishkills happened due to organic waste water discharge from certain paper mill's factories standing along the Edo River in Tokyo. The problems that influenced human health such as Minamata Disease, began to make their appearance around 1950s.

2.1.3 1960s

With out rapid economic growth in 1960s, water pollution becomes widespread and severe. Damage of human health by mercury contamination in the Agano River and that by Cadmium in the Jinzu River are called the second case of Minamata Disease and Itaiitai Disease, respectively. In 1967, the fundamental Basic Law for Environmental Pollution Control was enacted which promotes comprehensive measures against typical environmental pollution (water quality, atmospheric quality, soil contamination, subsidence, noise, vibration, and offensive odors). Water Quality Standards were established in this Basic Law. In 1970, the so-called "Diet for Environment Issues" was opened and adopted essential improvements in the legislation system. The former two acts were unified in the form of a new reinforced act "Water Pollution Control Law." A new act on prevention of marine pollution and maritime disasters was also enacted. "Ports and Harbours Law" was revised to direct regional authorities / governments to maintain god environment in the ports and harbours area.

2.1.4 1970s

After the new "Water Pollution Control Law", there still occurred serious pollution accidents. A large scale red tide in the Seto Inland Sea in 1972 destroyed coastal creatures and cultured yellowtail fish. Crude oil spilled out accidentally from an oil refinery factory along coast in 1974. Contamination of toxic chromium (VI) was detected in ground water in Tokyo due to illegal dumping of industrial waste.

For inner bays and enclosed water body, eutrophication and red tide's problems were accelerated owing to the high density of population and industrial activities along coast. In 1973, Interim Law for Environmental Conservation of the Seto Inland Sea was enacted. This law was revised in 1978 and was renamed "Law Concerning Special Measures for Conservation of the Environment of Seto Inland Sea", under which new reclamation projects are strictly limited in this area. In the same fiscal year, another legislation was introduced for the regulation of the total allowable organic load in addition to the conventional restrictions on concentration levels in waste water. This is targeted to effluents for the Seto Inland Sea, Tokyo Bay and Ise Bay. In PHRI, Purification Hydraulics Laboratory was established in 1975.

2.1.5 1980s

Only slow improvements have been made in water quality in enclosed water body. Main issue is eutrophication and toxic. Eutrophication associated with red tide and anoxia problems have been observed every summer in inner bays such as Tokyo Bay, Osaka Bay and Ise Bay. Eutrophication is also severe in lakes and reservoirs near cities. In 1984, "Law Concerning Special Measures for Conservation of Lake Water Quality" was enacted. "Water Pollution Control Law" was twice revised in 1989 and 1990 to prevent underground water pollution by toxic and institutionalize measures against domestic waste water. In 1988, Minamata Dredging Project was successfully finished.

2.1.6 Summary

General history for water quality preservation in Japan is tabulated in Table–1. Japanese map for water quality preservation history in also shown in Fig.-3. Roughly speaking, our history of water pollution problems is smmarized as:

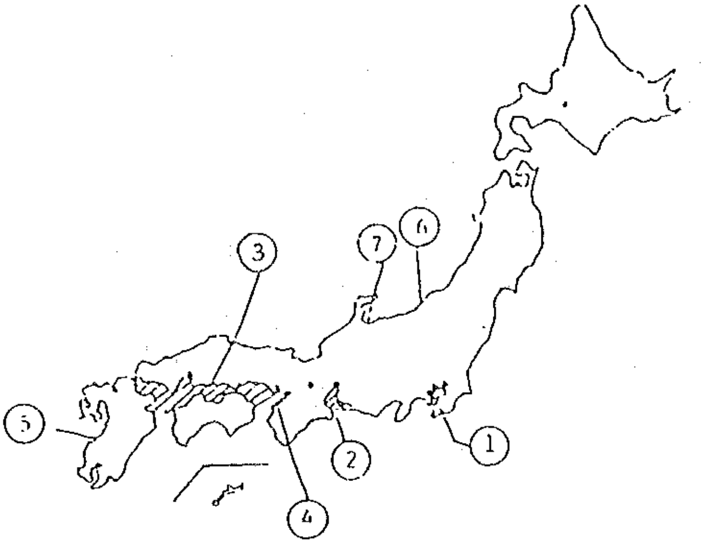
1. started initially with organic pollution and associated fishkill,
2. changed, as industrialization was developed, to eutrophication and toxic problems such as heavy metals and insecticides, and
3. is spreading into wide ranges and phases of water, including micro–pollutants in underground water and upstream reservoirs for drinking

2.2 Establishment of Water Quality Wtandards

2.2.1 Establishment of WQS

The Environmental Quality Standards (EQS) at first established by the Cabinet Decision in April 21, 1970. EQS for the public water are divided into two categories. One of those achieved and maintained to protect human health and the other achieved and maintained to conserve the living environment.

In the former category, national uniform standards are applied to all public water areas. In the latter category, standards are applied for three areas: rivers, lakes and reservoirs, and coastal water. Areas are classified with the consideration of the water usage, the degree of the water pollution etc.



Enclosed Bay/Inland Sea
(1) Tokyo Bay
(2) Ise Bay
(3) Seto Inland Sea
(4) Osaka Bay a part of Seto I.S.

(5) Minamata
(6) Niigata/Agano River
(7) Toyama/Jinzu River

Fig. 3 Japanese Map for Water Quality Preservation

2.2.2 Criteria for the Standards

Criteria for each standard listed up in Table-2,3,4,5, and 6.

2.2.3 Water Pollution Control Law

The countermeasures of water pollution control are to perform each countermeasure necessary to achieve and maintain as a goal the environmental quality standards based on the Basic Low for Environmental Pollution Control. Among these countermeasures of water pollution control, the following two constitute the most important elements.

- Control of discharge from industrial and municipal sources into public water areas by the Water Pollution Control Law
- Development of sewerage and sewage treatment system

2.3 Outline of Marine Environment Improvement Work

As shown in Table-7, an outline of the ports and marine environment improvement work has been implemented by the Ministry of Transport.
The recent progress of the main projects are as follws:

Work on waste oil disposal facilities was begun in 1967. In 1988, 133 facilities in 82 ports had been constructed (for 35 facilities in 35 ports had been constructed by port authorities). The total quantity of disposed oil from ships to those facilities was 4.26 *millionkl* in 1988.

Port pollution prevention work, as represented by the dredging of organic-mercury-contaminated sediment in Minamata Bay, began in 1972. In 1988, 18.57 $million m^3$ of sludge contaminated with mercury, cadmium and PCBs, and organic sludge was dredged at 43 ports in 46 districts.

Marine cleans-up work was begun in 1974. In 1987, 74,000 m^3 of floating refuse and 206,000 kl of floating oil had accumulated in inner seas and inner bays. These projects work under the direct supervision of the government.

These projects, coupled with waste-water regulations and various legal regulations, made a great contribution to the improvement of Japan's marine environment in the early 1970s.

3 Environmental Impact Assessment

3.1 Promotion of Environmental Impact Assessment

3.1.1 Environmental Impact Assessment

To prevents environmental pollution caused by large scale public works, the Environmental Impact Assessment (EIA) was first introduced in 1972 after the Cabinet's approval for the document "On Environmental Preservation Measures to Public Works". EIA was legally enforced under the Public Water Body Reclamation Law, the Port and Harbour Law and other specific laws for public works.

EIA calls for adequate survey, prediction, and evaluation of the possible environmental influence before the implementation of projects that could/might significantly affect the environment. The results are announced to the public, and the opinions of the local residents/inhabitants are gathered, so that sufficient precautions can be taken to protect the environment.

The Harbour Project under the Port and Harbour Law illustrate the basic concepts of future development, utilization, and conservation of each harbour. This Harbour Project is authorized legally by the Port and Harbour Committee, which consists of local governments, each representative for fisheries, ship owners, captains/sailors, transportation companies and son on. These harbour projects should incorporate EIA for the future utilization of designed harbours. The Second Part of the Harbour Project Document is for the EIA Report.

The Public Water Body Reclamation Law requires an examination of EIA for reclamation works and future use of new land before the reclamation license is issued. The license can be issued by Minister of Transport, Minister of Construction, or Minister of Agriculture and Fisheries, depending upon reclamation location. These ministers must ask for the opinion of Environmental Agency for a reclamation over 50 hectare ($> 500,000m^2$) or important area for environmental conservation.

Legal EIA is also applied to planning for power plants, controlled urbanization areas, and other projects including resort developments.

3.1.2 Implementation Scheme

In 1984, the Cabinet approved "Implementation of Environmental Assessment" and defined the Implementation Scheme for EIA, which covers the construction of roads, dams, railroads, airport, land reclamation (including filling and drainage), and land readjustment. Schematic process for this Implementation Scheme can be seen in Fig.-4.

3.1.3 Technical Background

For harbour projects and reclamation, main issues for EIA are:

1. changes of flow and/or dispersion due to new land and port facilities,
2. increase of pollutant load due to harbour activities, and
3. increase of turbidity due to construction works

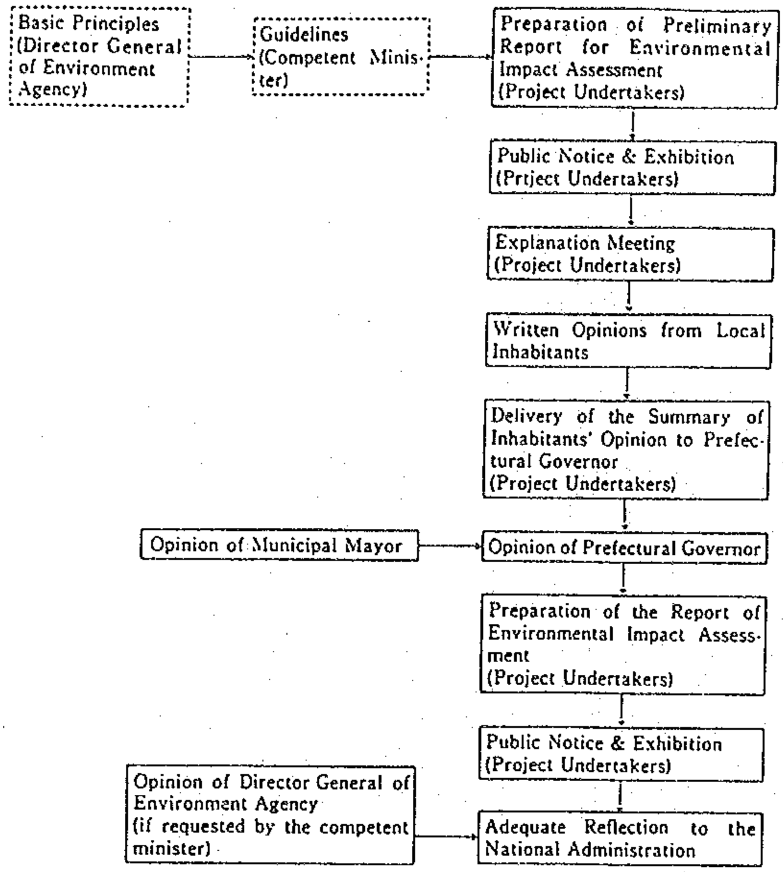


Fig. 4 Procedures Required by the Implementation Scheme for EIA

Changes of the EQS concentration near the site and reclamation land are assessed by scientific knowledge. Much effort has been made on developing technical methods and in improving the accuracy.

3.2 Methods of Assessing Environmental Impact

3.2.1 Mass Balance Method

To assesses environmental impact, objectives need to define clearly. A designated water mass and an amount of pollutant load give us basic information for initial condition of objectives.

Mass balance method is one of the most important principles for state of objectives. That can be written as:

$$\text{Change in mass} = \text{mass in} - \text{mass out} + \text{sources} - \text{sinks}. \quad (1)$$

"Mass in" is pollutant load that comes in to the designated water mass. "Mass out" is pollutant effluent from the water mass. "Source" and "sinks" are expressing the loss and the supply of mass due to some reactions. This equation denotes the change of pollutant mass in the designated water mass.

For the simplification of this equation, we use symbols as follows:

V :Designated water mass

C : Concentration of the pollutant

t :Time

W :Mass in

Q :Exchange volume of disignated water mass

Q_o :Mass out $= Q \cdot C$

k_{so} :Reaction rate for sources

k_{si} :Reaction rate for sinks

According to these symbolize Eq.(1) can be written as:

$$\frac{dC}{dt} = \frac{W}{V} - \left(\frac{Q}{V} + k_{so} - k_{si}\right) \cdot C. \tag{2}$$

The solution of Eq.(2) is

$$C_e = \frac{\frac{W}{V}}{\frac{Q}{V} + k_{so} - k_{si}}. \tag{3}$$

Where, C_e is equilibrium concentration of the pollutant in the designated water mass. For the decrease of C_e, followings are effective options;

1. increase of exchange volume of the water mass,
2. decrease of inflow load,
3. increase of the water mass,
4. decrease of reaction rate for sources,
5. and increase of Reaction rate for sinks.

This basic equation (3) shows which term is effective to decrease pollutant concentration. It denotes qualitative contribution of each term. This is a simple example, but it gives us useful information on WQM's strategy.

3.2.2 Techniques for Assessment

The simple analysis is introduced in above section. For assessment in a case, we have to know the more detail state of objectives. Especially, current, diffusion of contaminants, and nutrient circulation are major issue for the assessment.

We have two major techniques to assess these objects. One is a hydraulic experiment or a laboratory test, the other is a numeric simulation.

Table–3.2.2 shows comparisons between these two techniques.

Generally speaking, if parameters (for physic, chemistry, and biology) are well known, numerical simulation is very useful tools. Unless well established model for numerical simulation, results of the simulation are meaning less.

The selection between hydraulic model and numerical model depends on the objectives of assessment. On executing such hydraulic experiments or numerical simulation, some of the greatest difficulties are that lack of field data cause the uncertainty of target and input data to the model.

For utilized these methods for assessment, we should know the limitation of each experiment and simulation. Some details of these methods are described in later section.

3.3 Hydraulic Experiment

3.3.1 Equipments

Hydraulic model experiment is the useful technique to investigate the influence on tidal current and substance dispersion.

(Hydraulic model basin)

Hydraulic model basin requires a certain scale of model. Usually model's scales are one over several hundreds in vertical and one over several thousands in horizontal.

The scale of model is depends on the projects. Typical size of the model basin is several decade meters in horizontal length, and several decades centigrade meter to several meters in vertical. The biggest model is "1973 Seto Inland Sea" model. This model is about 250 meter long and 100 meter wide.

(Model of geographical configuration)

Geographical configuration usually set by a soil mound covered with a concrete. It has to be mentioned about sealings.

Newly used material for the configuration is FRP. By using FRP model, we can cut down the time for the construction.

(Tide generator)

Usually we use two types of tide generator. One is pneumatic tide generator and the other is mechanical tide generator.

Fig.-5 shows pneumatic type tide generator.

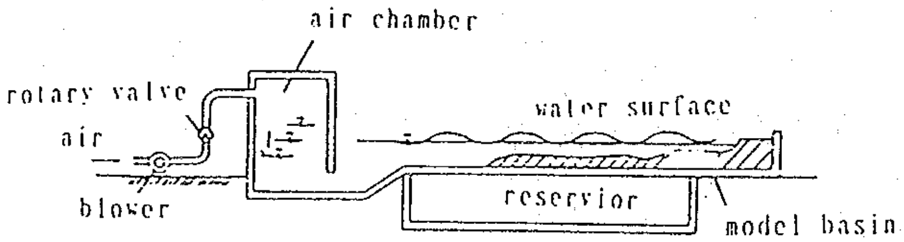


Fig. 5 Pneumatic Tide Generator

Pneumatic tide generator has an air chamber. Air pressure in the chamber was controlled with a valve and a blower. When high pressure in the chamber, water mass in the chamber comes out to the model basin. When low pressure in the chamber, water mass in the model basin comes buck to the chamber. It makes tide in the model basin. The pneumatic tide generator can be used for wide range tide. But, it is difficult to control the pressure in the chamber.

Mechanical tide generator has flaps at the end of the basin. When flap lay down, the volume of basin increase. When flap setting up, the volume of basin decrease. It makes tide in the model basin. Mechanical tide generator makes fewer disturbances for the water mass in the basin. But, it is more difficult to control the flaps.

(Other equipments)

Pump system is required for generate the independent flow with tide. It is very important to mention not only capacity of the pump system, but also rectification of the flow. Slits set in front of the diffuser and jetties are useful equipment for the rectification.

Anemometer, tracer, wave gage, video system etc. is also important equipment.

3.3.2 Similarity Law

When we carry out the hydraulic model experiments, it is necessary to satisfy the similarity law between the prototype and the experiment.

The similarity law can be derived from governing equation for the prototype and the model. But, it is impossible to satisfy strictly the similarity law for substance dispersion and current in the model. Today, Froude's similarity law with small distortion ratio model is commonly use in hydraulic experiments.

Froude's similarity law based on non dimensional Froude's number (Fr).

$$\mathrm{Fr} = \frac{U}{\sqrt{gH}}. \tag{4}$$

Where, U is a respective velocity ($U = L/T$), g is acceleration of gravity, H is a respective vertical length, L is a respective horizontal length, and T is a respective time scale.

According to Froude's similarity law, we obtain following scale ratios as shown in table–9.

3.4 Numeric Simulation

3.4.1 Governing Equations

Numeric simulation is based on governing equations for the object phenomena that we wanted to know.

Governing equation of tidal current are consisted of continuity equation and momentum equations. Continuity equation is

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0, \tag{5}$$

and momentum equations in each components are

$$\begin{aligned}\frac{\partial(\rho u)}{\partial t} &+ \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} \\ &= \rho v f - \frac{\partial P}{\partial x} + \mu_h\left(\frac{\partial^2(\rho u)}{\partial x^2} + \frac{\partial^2(\rho u)}{\partial y^2}\right) + \mu_z\left(\frac{\partial^2(\rho u)}{\partial z^2}\right)\end{aligned} \tag{6}$$

$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z}$$
$$= -\rho uf - \frac{\partial P}{\partial y} + \mu_h(\frac{\partial^2(\rho v)}{\partial x^2} + \frac{\partial^2(\rho v)}{\partial y^2}) + \mu_z(\frac{\partial^2(\rho v)}{\partial z^2}) \quad (7)$$

$$\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z}$$
$$= -\rho g - \frac{\partial P}{\partial z} + \mu_h(\frac{\partial^2(\rho w)}{\partial x^2} + \frac{\partial^2(\rho w)}{\partial y^2}) + \mu_z(\frac{\partial^2(\rho w)}{\partial z^2}) \quad (8)$$

in which, x, y, z is Cartesian coordinate, t is time, u, v, w is velocity in x, y, z directions, P is pressure, ρ is density, g is gravity acceleration, μ_h, μ_z is eddy viscosity in horizontal and vertical directions, and f is Coriolis' parameter.

3.4.2 Finite Difference Method

We want to get a solution of governing equations. Governing equations are written as Partial Differential Equation (PDE). These equations state infinite limit of a virtual small scale control volume.

In the computer, we can treat only finite discrete calculations. Then, we have to translate governing equations for Finite Discrete Equations (FDE).

The sequence to solve PDE by FDE shows in Fig.-6. In this sequence, we have to consider:

- consistency of discretization (1),
- availability of solver (2),
- and stability of the solution of FDE (3).

PDE	$\Longrightarrow$	solution of PDE
(1)↓ discretization		(3)↑ convergence
FED	$\longrightarrow$ (2)solving	solution of FED

Fig. 6 Sequence to Solve PDE

(Grid generation)

For discretization, computational grid has to determine. Usually, grid based on Cartesian coordinates or Polar coordinates.

When we generate a grid system, following instruction recommend to be consider:

- sufficient resolution for geographical configuration,

(a) Regular Mesh (b) Staggered Mesh

Fig. 7 Mesh Systems

- possibility of minimize the grid distortion,
- and direction of the coordinates for adaptation of boundary condition.

A patching grid and an adaptive grid also can be used to get higher resolution of the grid.

Next step of grid generation is mapping variables to the grid. There are two major mapping methods. One is a regular mesh system and the other is a staggered mesh system. Each system is shown in Fig–7.

In the regular mesh system, all variables mapped in the same node point in the grid. The programing sequence becomes more simple than that for the other mesh system. And, the implementation of boundary condition is easy.

In the staggered mesh system, scalar variables (p, ρ) are mapped in the center of grid. Other vector variables (u, v, w) are mapped in the midpoint of two node points in the grid. The programing sequence becomes more complex than that for the regular mesh system. And, the implementation of boundary condition is difficult. Furthermore, a stability of FDE is improved for spatially oscillation in the solution.

(Discretization)

The simple example of a discretization is shown by first derivative of junction $f(x)$. A first order forward discretization is able to written as:

$$\frac{df(x)}{dx} = \lim_{\delta \to 0} \frac{f(x_i + \delta x) - f(x_i)}{\delta x}. \tag{9}$$

The schematic image of the discretization is shown in Fig–8.

As shown in Fig–8, there are many definitions for the discretization. Some of them are listed in Table–10.

After discretization of PDE to FDE, we can use time–marching method to obtain optional time's solution. There are many time–marching methods, and that is still one of main issues for the computer science. At this paper, only names of these methods are listed up.

1. Explicit Method
   (a) Euler method
   (b) Leap Frog method
   (c) Predictor Corrector method

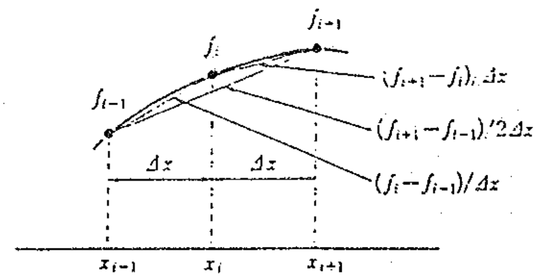


Fig. 8 Definition of Discretization

(d) Adams–Bashforth method

(e) Runge–Kutta method

2. Implicit Method

(a) Euler method

(b) Crank–Nicolson method

(c) Alternating Direction Implicit method

(d) Splitting method

(Stability)
Stability of FDE is able to test by using Fourie series of each derivative term. In general, implicit methods have more stability than explicit methods.

For example, Alternating Direction Implicit Method's stability condition is able to describe as:

$$\frac{\delta t}{2} < \frac{\alpha \delta S}{\sqrt{g h_{max}}}. \tag{10}$$

where, S is a gird size, h_{max} is maximum water depth, and α is empirical constant (1–3).

3.4.3 Tidal Current Model

According to Eq.(5)–(8), we obtain governing equation for three dimensional tidal current. If it is possible that generate three dimensional grid, we can solve these equations by using FDE. Usually, we have to simplification for these equations by restrictions of computational time and lack of calibration data.

Classification of these equations by dimension is listed as:

- One–dimensional model,
- Depth–averaged two–dimensional model,
- Depth–averaged two–dimensional two–layer model,

- Depth–averaged two–dimensional two–level model,
- Three–dimensional multi–layer model,
- Three–dimensional multi–level model,
- and Three–dimensional model.

Depth–averaged two–dimensional model is mostly used in assessment. Governing equations are expressed as follows:

$$\frac{\partial\zeta}{\partial t} + \frac{\partial[(h+\zeta)u]}{\partial x} + \frac{\partial[(h+\zeta)v]}{\partial y} = 0, \tag{11}$$

$$\begin{aligned}\frac{\partial u}{\partial t} &+ u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} \\ &= fv - g\frac{\partial\zeta}{\partial x} - \frac{\tau_x^b - \tau_x^s}{\rho(\zeta+h)} + A_h\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right),\end{aligned} \tag{12}$$

$$\begin{aligned}\frac{\partial v}{\partial t} &+ u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} \\ &= -fu - g\frac{\partial\zeta}{\partial y} - \frac{\tau_y^b - \tau_y^s}{\rho(\zeta+h)} + A_h\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right).\end{aligned} \tag{13}$$

Where, definition of symbols is shown in Fig–9. And, sample of computational result is shown in Fig–10.

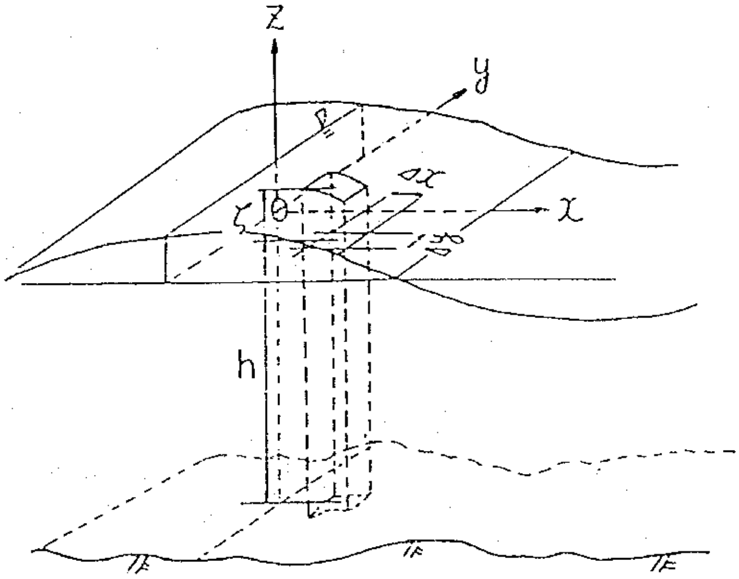


Fig. 9 Definition Sketch of Two–Dimensional Model

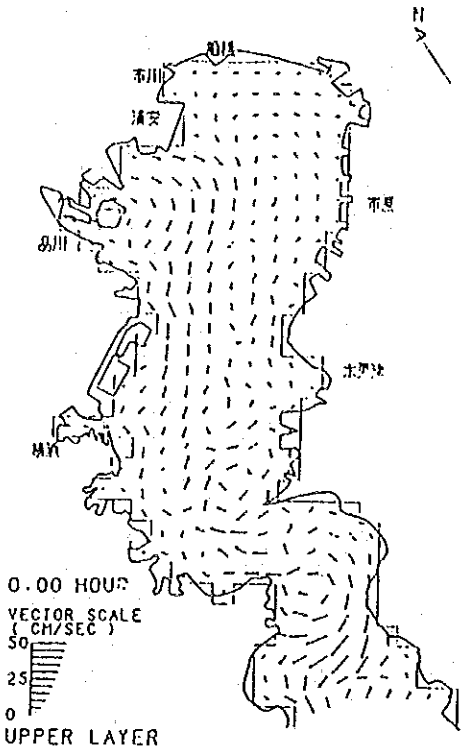


Fig. 10 Sample of Computational Result

3.4.4 Substance Diffusion Model

The mass transport equation for three-dimensional turbulent flow is express as:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}e_x\frac{\partial c}{\partial x} + \frac{\partial}{\partial y}e_y\frac{\partial c}{\partial y} + \frac{\partial}{\partial z}e_z\frac{\partial c}{\partial z} + \frac{r_i}{\rho}, \tag{14}$$

where, u, v, w are the time-averaged velocity components, c is the local concentration, e_x, e_y, e_z are turbulent diffusivity, and r_i is the rate of generation (or decay) of substance per unit volume of fluid.

3.4.5 Water Quality Model

For water quality model such as COD, DO, etc., non-conservative substance materials should be considered.

First, we have to know the mechanism of ecological system for marine environment as shown in Fig.-11.

Next, pick it up the governing process in the system to state objectives of wate r quality as shown in Fig.-12. According to this operation, we know how many compartments have to include in the model.

Finally, we get the model include ecological effects. Usually, non-conservative property of substance materials is considered by the source term or sink term in Eq.(14).

The rate of generation (or decay) of substance (r_i) is usually expressed by first order reaction rate (K) as follow:

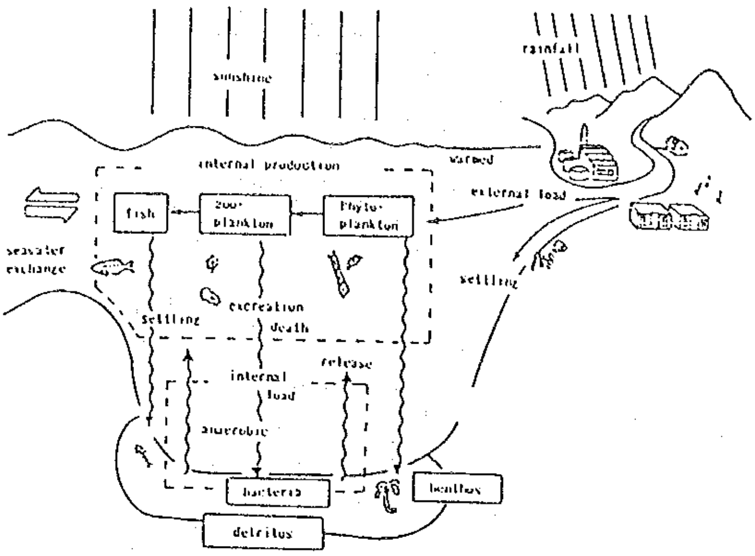


Fig. 11 Schematic view of natural ecosystem

$$\frac{\partial c}{\partial t} = r_i = K \cdot c \tag{15}$$

Fig.-13 shows a result of water quality model. That figure shows distribution of COD concentration in the bay.

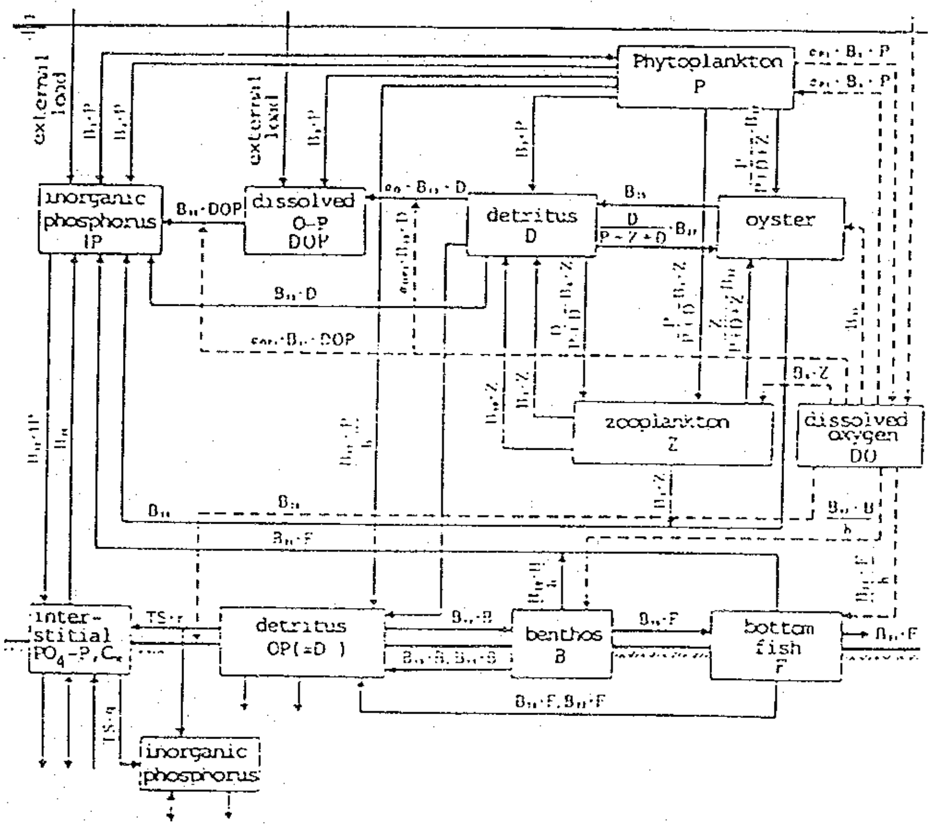


Fig. 12 Mutual Relationship Between each Compartment

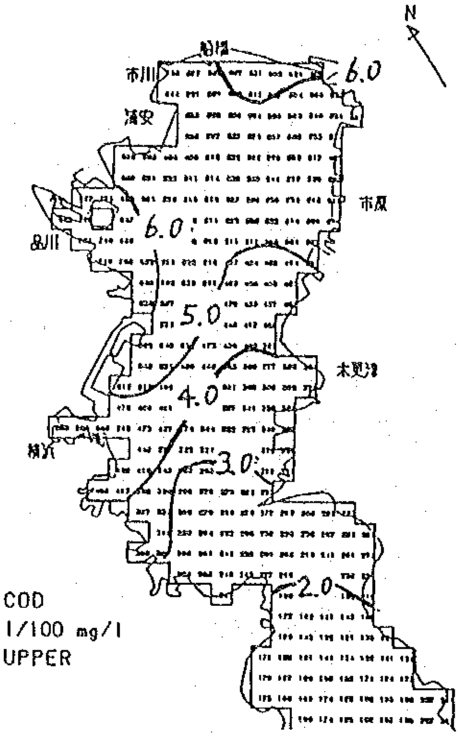


Fig. 13 Sample Result of Water Quality Model

4 Case Studies

4.1 Surface Flow and Particle Settling in a Coastal Reed Field

Using two models, one for flow and the other for settling in shallow wetland, we can estimate the clarification potential of a certain reed field under a given hydraulic condition and particle load. Numerical experiments show that fine particles tend to accumulate on the bottom of a reed field as often observed in natural wetlands.

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SURFACE FLOW AND PARTICLE SETTLING IN A COASTAL REED FIELD

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ABSTRACT

Hydraulic roughness of reed stems in shallow surface flow is discussed under low current velocity. The roughness coefficient, defined as a Manning's formula, depends upon depth and velocity in this flow. Depth and velocity, in turn, are altered by roughness through water surface slope. This interaction among velocity, depth and roughness is required to solve these three parameters simultaneously for the prediction of the surface flow in a reed wetland. Stem roughness can be expressed as a function of Reynolds' number, similar to that for a single cylinder. Assigning this function, an iteration method gives us a suitable set of three parameters easily.
Settling experiments show that stems promote vertical mixing of fine particles in shallow flow. The model of vertical uniform SS concentration is more suitable. Though the observed data fluctuated widely, the apparent settling velocity of fine particles in the flow was very close to the settling velocity in quiescent water.
Using the above two models, one for flow and the other for settling in shallow wetland, we can estimate the clarification potential of a certain reed field under a given hydraulic condition and particle load. Numerical experiments show that fine particles tend to accumulate on the bottom of a reed field as often observed in natural wetlands.

KEYWORDS

coastal wetland, reed field, hydraulic roughness, settling, numerical model

INTRODUCTION

Functions of wetlands for water quality control are varied widely. Among them, settling of particulate organics onto the bottom surface inside a coastal wetland also contributes to water quality improvement in an inner bay. With sediments accumulation inside, a reed field tends to advance its territory toward the littoral zone every year. Fig.1. shows the development of the reed front, which can be analyzed through aerial photos taken by National Geographical Survey Institute for mapping. This coastal reed field has one small river at the bottom end, and is facing to a shallow inlet. The inlet is connecting to a small bay opening to the Pacific Ocean near the entrance of Tokyo Bay. Ground level of the reed field gradually rose higher at the mean rate of 5-10 cm/y for two years. Considering the observed rates of horizontal development and vertical rising, the authors estimated the solid accumulation rate roughly as 7-14m^3/y, which is almost equivalent to 15-30 kg-N/y and 10-20 kg-P/y (Hosokawa, *et.al.*,1991). In this reed field of 3000m^2, nutrient uptake rate by reed stems is separately estimated as 80 kg-N/y and 6 kg-P/y (Horie, *et.al.*,1987). Both settling and uptake functions in this area contribute to the nutrient stock capacity at the similar order. Settling at wetlands can be expected as one of the major functions for water quality purification. Hydraulics of the surface flow and sediment settling are discussed here.

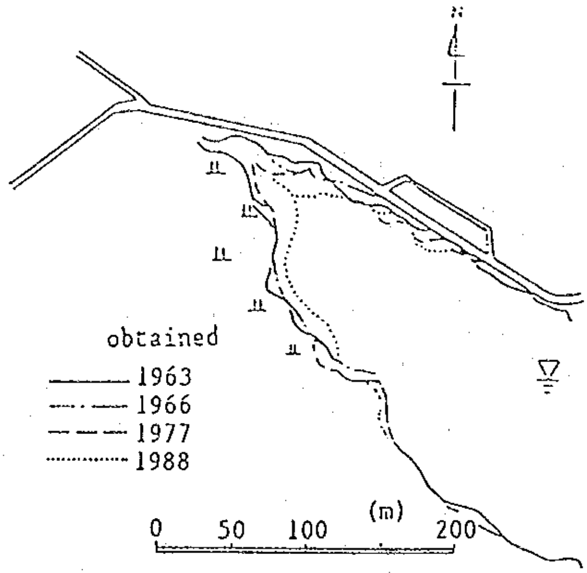


Fig.1. Development of coastal reed front toward littoral zone

FLOW MODEL

Surface flow at shallow zone with reed is usually slow and calm. Water depth of the reed field is normally 10-50cm along coast and river mouth. Taking water depth as representative length(L), we can estimate nondimensional Reynolds' number (Re = Lu/v) of the flow as the order of 10^2 -10^4. This small order expresses the flow is turbulent but very close to transition to laminar flow. For wetland flow, Manning's formula has been widely applied to the estimation of mean velocity, though this equation was first formulated for fully developed turbulent flow. Manning's equation is :

$$u = \frac{1}{n} R^{2/3} I^{1/2} \qquad (1),$$

u = mean velocity,
n = Manning's roughness coefficient,
R = hydraulic radius,
I = energy gradient.

For the flow of low Reynolds' number, n depends on not only its equivalent roughness but also Reynolds' number with depth. The exact relationship between n and Re is not clear for low Re flow except the channel flow on smooth bottom surface (Kouwen and Unny, 1973). Generally, n becomes larger as Re decreases at low Re region. Kouwen's equation for n_b is as follows:

$$n_b = 10^{(1.453 - 0.559 \log Re)} \qquad (2),$$

n_b = Manning's coefficient for bottom,
Re = nondimensional Reynolds' number taken water depth as representative length.

Hosokawa *et. al.*,(1992) pointed out after some channel experiments that the friction of reed stems is effective at the same order as bottom roughness. Accordingly, both bottom roughness and stem resistance are effective for the mean velocity of surface flow. Total energy loss (I) can be expressed as the sum of each loss. If we can get appropriate value of n_b for bottom roughness, we can estimate the energy loss due only to bottom roughness (I_b) through Eq.(1) under the known condition of u.
Energy loss due to the stem lines (I_d) is expressed as:

$$I_d = T_d \frac{Ar}{R} \quad (3),$$

$$T_d = C_d D h \left(\frac{u^2}{2g}\right) \quad (4),$$

I_d = energy loss gradient due to stems,
T_d = drag force affecting on one reed stem,
A_r = density of stems par unit area,
C_d = drag coefficient of stem cylinder in umiform flow,
D = diameter of stem,
h = water depth,
g = gravity accelaration.

If we can choose appropriate value of C_d for the given condition, then we can estimate the resistance effect of stems on flow. Hosokawa *et.al.*,(1992) also found that C_d for a stem is quite similar to that for a cylindrical pipe for Re= 4×10^2 - 2×10^3, though the reed stem has little hairs on its surface. C_d for a cylindrical pipe is altered with mean velocity as well (Schlichting, 1979). For the low Re region, C_d increases in its value as u decrease. Examining the Schlichting's chart, following function was chosen for low Reynolds' flow.

$$C_d = 3.25\,(Red)^{-0.17} \quad \text{for } 2\times10^1 < Red < 10^3 \quad (5),$$

Red = Reynolds' number taken stem's diameter (D) as a representative length, defined as Red = Du/ν.

Both n and C_d increase as the flow becomes faster. Then, energy gradient becomes larger against the flow resistance. Increase of water surface gradient due to larger energy gradient changes the mean velocity. Change of the mean velocity affects n and C_d again. Thus, in low Re flow, roughness, water elevation and velocity are deeply related each other. As the parameters of n and C_d cannot be expressed explicitly by u and I, a suitable combination of three parameters (roughness, water elevation and mean velocity) should be evaluated simultaneously. We have developed the numerical iteration method shown in Fig.2. This method can also be applied for vertically-averaged 2-D flow field.

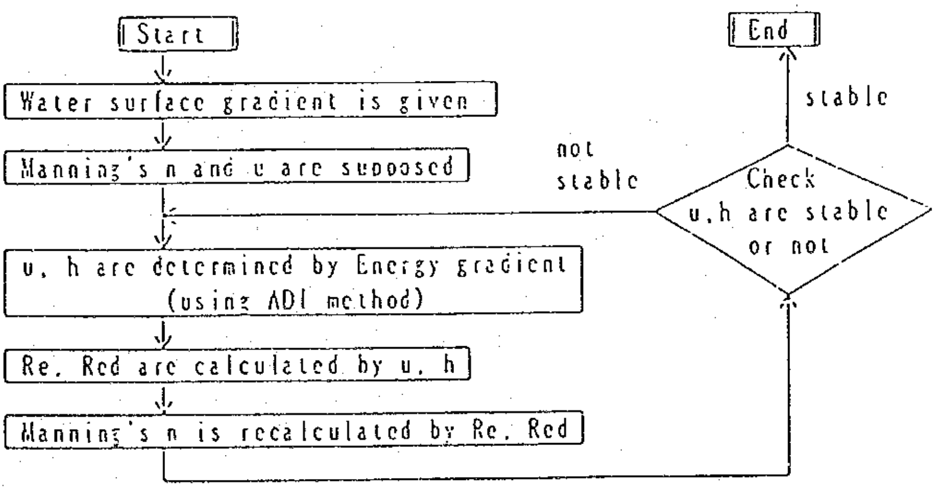


Fig.2. Itaration flow in the numerical model for finding a suitable set of 3 parameters

SETTLING EXPERIMENTS

Theory

Particulate matters settle down to the bottom surface during the transportation by flow. In one directional channel flow system, change of particulate concentration (C) with time is expressed for uniform depth and particulates of uniform settling velocity as:

$$\frac{dC}{dt} = -u\frac{dC}{dx} + E_x\frac{d^2C}{dx^2} + E_z\frac{d^2C}{dz^2} - \frac{w_0}{h}C \qquad (6),$$

C = particulate concentration,
t = time,
x = longitudinal distance,
z = vartical distance,
E_x and E_z = diffusion coefficients for horizontal and vartical direction respectively,
w_0 = settling velocity.

For wetland, suspending particles are usually fine. Considering fine particles with w_0 less order than 10^{-1} cm/s, and vertically complete mixing in shallow flow, then the third term of the right hand side in Eq.(6) can be eliminated as C becomes vertically uniform. Then, the steady state solution for Eq.(6) is obtained as:

$$Ce(x) = C0\exp\left(\frac{u - (u^2 + 4w_0E_x/h)^{1/2}}{2E_x}x\right) \qquad (7),$$

Ce(x) = steady state distribution of particle concentration,
C0 = initial concentration at x=0.

If h is order of 10cm, E_x is order of $1cm^2/s$, and u is order of 1cm/s as often seen at wetlands, then the nondimensional estuary number (w_0E_x / u^2h) is far less than unity. In this case, the solution is more simple as:

$$Ce(x) = C0\exp\left(-\frac{w_0x}{h\,u}\right) \qquad (8).$$

This solution means that particulate concentration (Ce(x)) decreases exponentially with travel time(x/u). So, if we know the appropriate settling velocity in flow, then we can estimate the concentration distribution.

Channel Experiments

We set six straight channels (L, W, h = 20m, 1m, 0.2m) inside the natural coastal reed field at Sendai Port. Along the flow, five sampling sites were set at every 4.5m as shown in Fig.3. In one channel out of every two, we cut off all reed stems and smoothed the bottom. Another contained natural reeds with the density of $130shoot/m^2$. Large water tanks were placed on higher mound and turbid water was introduced into six channels with constant discharge rate and constant water head during one set of experiment. Weir height set 10cm at the each channel end. For one experimental run, we took water samples three times at 30minutes intervals after obtaining the steady state condition. Petri dishes were placed on the channel bottom for measuring settling flux of SS. The value of (flux)/(SS concentration) at each point shows the time averaged settling velocity there. As it is very difficult to measure the accurate flux, data should be as a reference to w_0. Separately from settling experiments, we also conducted tracer experiments for the flow analysis with NaCl.

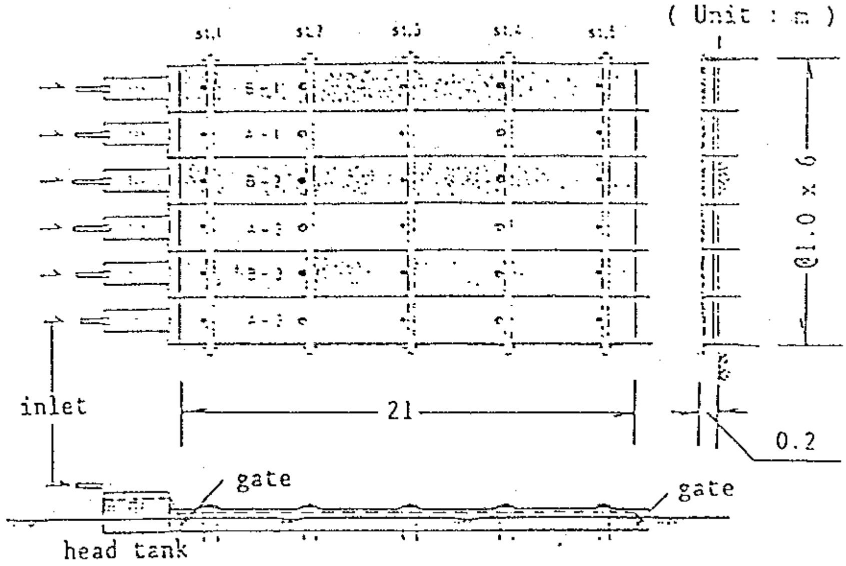


Fig.3. Experiment channels for settling

Results and Discussions

Typical distribution of SS with x is shown in Fig.4. for both vegetated and cutted-off channels. We can treat these two curves as exponential decrease. Plotting log(C/C0) vs. x/u, we can estimate the value of w_0/h as the slope of the regression line. Then, the apparent settling velocity in flow (w_0) is calculated for each experiment. Obtained data fluctuated widely but within the range of 1.5-3.0m/d. Mean w_0 is 2.1m/d (= 2.4×10^{-3}cm/s) with the standard deviation 0.7m/d for 19samples. This value is similar to the estimated ratio between observed flux vs. SS concentration (2.2 + 0.6m/d for 24samples). Partially due to the variety of data, we can find no clear dependency of w_0 on initial concentration, velocity or vegetation. Though the continuous research is necessary for the more accurate estimation of w_0 in flow, it is possible to apply w_0 in quiescent water for the practical estimation of SS distribution. Tracer experiments show that E_x is the order of 10^0 - 10^1cm^2/s for u = 0.5-1.0cm/s. Concentration of NaCl was observed vertically uniform in reed channels by the strong vertical mixing.

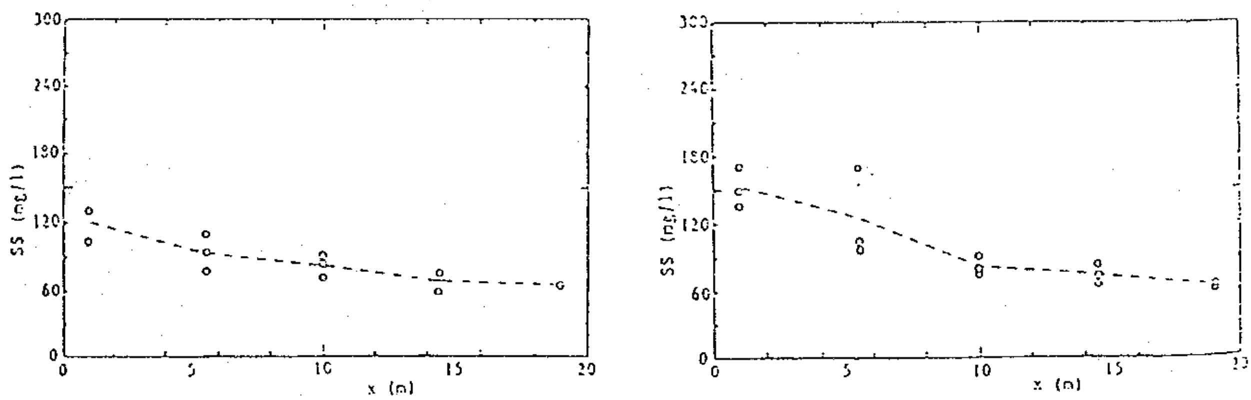


Fig.4. Distribution of SS with distance (left: without reed, right: with reed)

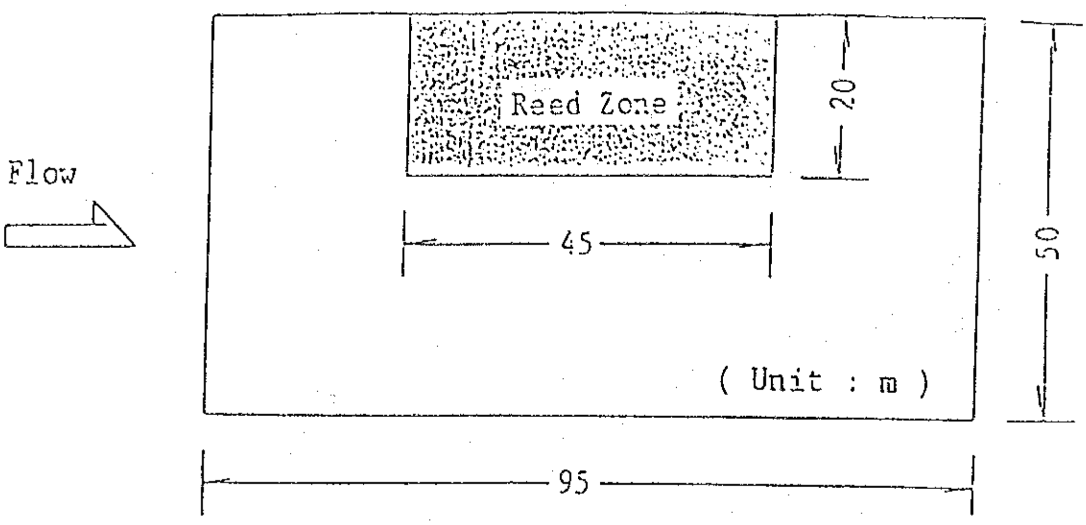


Fig.5. Configuration of model reed area (unit: m)

SETTLING MODEL

Conditions

If we can assign suitable w_0 and E_x to Eq.(6), we can get distribution of C under a given flow field. Extendeing 1-D Eqs.(1) and (6) to horizontal 2-D model, we tried numerical experiments to evaluate the effects of settling velocity on the steady state SS distribution (that is: spatial distribution of Ce/C0). We chose the simple configuration of a coastal reed field in one directional flow as shown in Fig.5. In a rectangular area (95m x 50m) of coastal sea, rectangular reed field (45m x 20m) is placed with reed density of 150shoot/m^2 and the stem diameter of 1.0cm. At the upper end of flow, water elevation is set 1cm higher than that at the down end. So, the initial water surface gradient is 1/9500. Depth is uniform and chosen as 30cm and 10cm, and settling velocity as 10^{-1}cm/s and 10^{-3}cm/s.

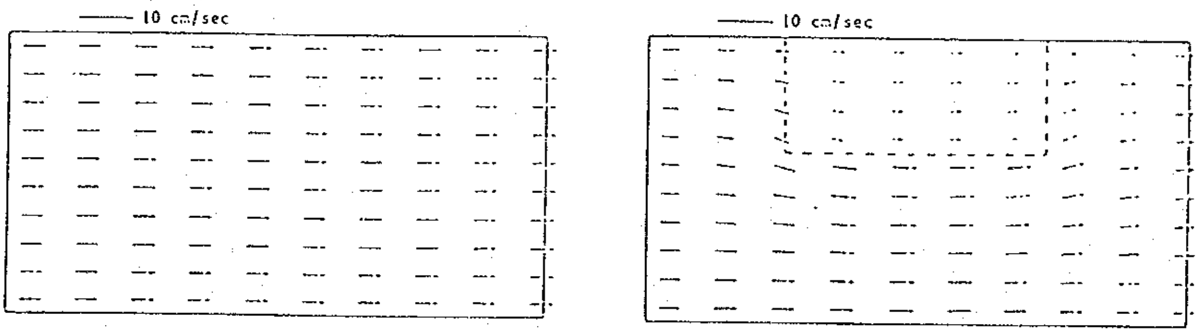
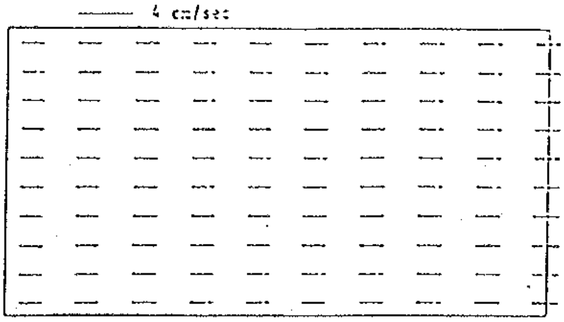


Fig.6. Calculated flow field for 30cm depth (left:without reed area, right:with reed)



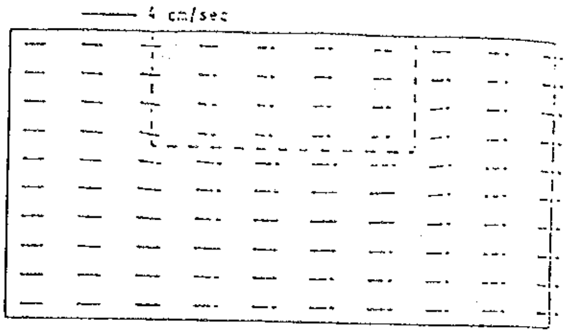


Fig.7. Calculated flow field for 10cm depth (left:without reed area, right:with reed)

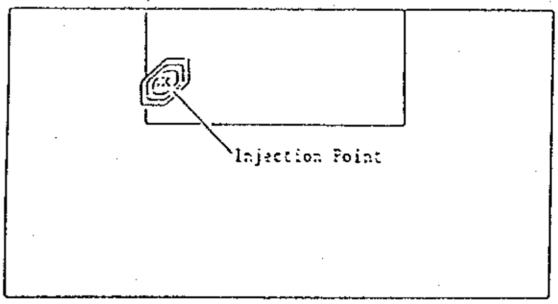


Fig.8. Ce/C0 distribution for w_0=0.1cm/s (injection inside reed area, depth 30cm)

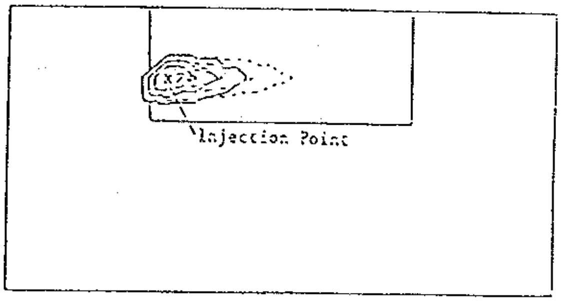


Fig.9a. Ce/C0 distribution for w_0=0.001cm/s (injection inside reed area, depth 30cm)

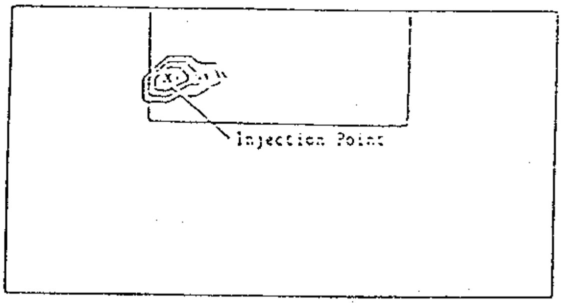


Fig.9b.Ce/C0 distribution for w_0=0.001cm/s (injection inside reed area, depth 10cm)

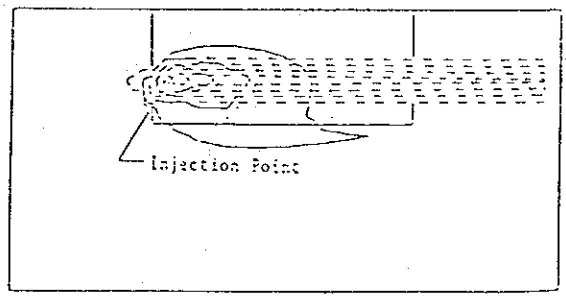


Fig.9c.Ce/C0 distribution for w_0=0.001cm/s (injection inside reed area, depth 100cm)

Calculation Results

Flow field Calculated flow fields are shown in Fig.6. for 30cm depth and in Fig.7. for 10cm. Due to the stem friction, flow near shore line turns its direction to off shore as it approaches to the reed field. Inside the reed field, velocity is smaller. Without reed field, water flows parallel to the shore line with same velocity over the area.
Comparing the flow in flat area without reed, velocity for 30cm depth (4.2cm/s) is 2.5 times faster than that for 10cm (1.6cm/s). Effect of the depth on velocity is clear when flow comes near and into the reed field. Comparing velocity inside the reed field with that at the off shore area, decrease of the velocity inside the reed field is drastic for the deeper case. It is because larger depth makes the bottom roughness less effective and the stem friction more significant. For 30cm depth, velocity is around 1-2cm/s inside reed field, which is almost 1/3-1/2 of the velocity at off shore area.

SS distribution Relative concentration (Ce/C0) is distributed as Fig.8. for w_0=0.1cm/s and Fig.9. for w_0=0.001cm/s. Contour lines are drawn at every 0.25 intervals. A cross mark (x) on each figure indicates the injection point of turbidity, where Ce/C0 is always 1. Thick line shows the distribution with the reed field and broken line without the reed field. For 30cm depth, contour lines of the two cases (with/without reed) are very close for w_0=0.1cm/s. For this depth, it takes about only 300sec for the large particles with w_0=0.1cm/s to settling down. Concentration of larger particles, under the shallow and slow flow condition, seems influenced little by the existence of reed. For finer particles, on the other hand, existence of reed field makes different distribution of the SS concentration. Decrease in velocity inside the reed field gives a significant effect due to longer suspension period. The difference becomes larger as the depth of up to 100cm in Fig.9c.

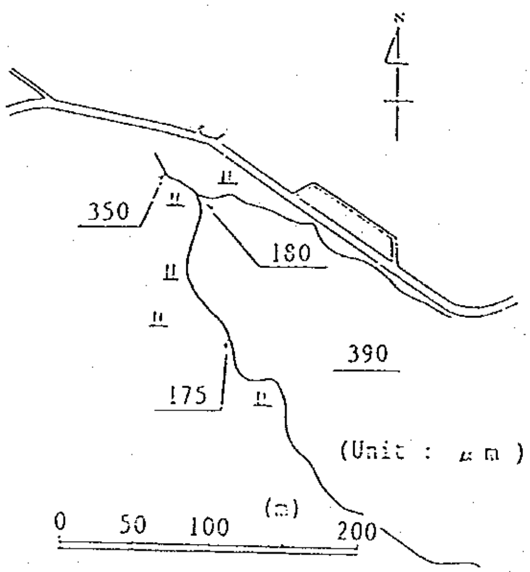


Fig.10. Distribution of sediment diameter (d_{50}) around reed field

DISCUSSIONS

From the numerical experiments, we can find out the following tendency;
a). flow resistance of reed stems is more significant when the depth is deeper,
b). fine particles are accumulated inside the reed field easier than large particles.

We can often observe along coastal wetlands that sediment diameter inside the reed field is finer than that of outer area. Fig.10. shows the mean diameter(d_{50}) distribution at the same inlet as shown in Fig.1. In front of the reed field, d_{50} is finer. Self development of the reed area as seen in Fig.1. as well as d_{50} distribution is not contrary to the results of our numerical experiments. By the settling model combined with the flow model, accumulation potential of particulate nutrient can also be predicted assigning nutrient contents in fine particles.

CONCLUSIONS

Among various contributions of wetlands to the water quality improvement, settling of particulate organics onto the bottom surface inside the reed field is discussed from the view point of the hydraulics for low Re flow. Followings are the conclusions here;

a)Assigning C_d for stems and n_b for bottom sediments as functions of Reynolds' numbers, a suitable set of mean velocity, water elevation and total roughness can be obtained by the iteration method.

b)The mean velocity inside the reed field becomes smaller due to the flow resistance of reed stems. Decrease of velocity is more significant in deeper condition.

c)From the practical point, SS distribution in low Re flow can be estimated assigning the settling velocity of particles in quiescent water.

d)Numerical experiments show that fine particles with the settling velocity of 0.001cm/s are significantly accumulated there when they are injected in the reed field. This tendency does not contradict the observation results at natural reed field in a coastal marsh. As fine particles contain high concentration of nutrients and organics, settling at wetlands is one of the important function for the water quality management.

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4.2 New Idea on Waterfront Development Harmonic Design for Space Utilization and Water Quality Improvement

For waterfront development in inner bays, it is essential to improve water quality for comfortable coastal environments. A concept of creating new water-affinity space along shallow coasts is discussed with the consideration of sea surface as an attractive environmental resource. Economical water qurification should harness natural energies and biological activities. Case studies are also conducted.

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NEW IDEA ON WATERFRONT DEVELOPMENT HARMONIC DESIGN FOR SPACE UTILIZATION AND WATER QUALITY IMPROVEMENT

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ABSTRACT

For waterfront development in inner bays, it is essential to improve water quality for comfortable coastal environments. A concept of creating new water-affinity space along shallow coasts is discussed with the consideration of sea surface as an attractive environmental resource. Economical water purification should harness natural energies and biological activities. Case studies are also conducted.

INTRODUCTION

In Japan, social needs for easy access to comfortable waterfront recently become stronger with the change of the life style of urban citizens. In this paper, we propose a new concept to purify the surrounding eutrophic water so that waterfront developments can provide citizens more suitable environment to its utilization. We try to apply the " goal-set-up " type approach in stead of the conventional " problem-solving " type one. From the strategic point of view, we believe that the former approach is quite powerful for 1)awakening social needs, 2)making areal development concept, 3)rearranging the present technology more clearly to find out objects for technological development[1]. This goal-set-up type approach also requires us to consider the water treatment economically. We are trying to use natural energies and biological activities which are found easily at shallow coasts. For realistic researches, we conduct some case studies on conceptual designing, which do not necessarily mean real projects.

1. Characteristics of natural environmental resources

The natural environmental resources such as atmosphere, rivers and the sea give citizens various benefits. Kitabatake[2] summarized four main functions of natural environment as environmental resources. Those are,

1) transport, diffusion, stock or assimilation of pollutants,
2) supply of raw materials for economical activities,
3) supply of services for human life,
4) supply of amenity/affinity services and relaxation.

Accordingly, the management of the environmental resources, including that of amenity, is a matter of public concern.

For the appropriate utilization of natural environments, following discussions should be necessary. 1)social needs for the concerned area, 2)environmental goal and responsibility for the management of the resources, 3)characteristics of the natural environmental, and selection of effective measures for the goal, 4)evaluation for the "goal and means" set. In Japan, port authorities or regional governments have initial responsibility for the environmental management inside ports and harbours.

2. Social needs

Water affinity or accessibility can be categorized into the following three levels, 1) watching the sea surface, 2) touching water by feet and/or hands, 3) bathing in the water. The utilization level will vary from place to place depending on natural and social conditions as well as environmental condition. Then, the environmental goal to achieve will vary depending on the each utilization level.

The Yokohama City Port Bureau conducted a hearing survey for its citizens about the port affinity. Most part of the public coastal area in this port is arranged for the watching level. They recognized the Port as an attractive, enjoyable, and clear open place. At the same time, they also pointed out the water pollution near the shore, and bad smell due to the eutrophication. They claimed, first of all, the protection from the water pollution rather than the traffic accessibility. The Prime Minister's Office, the national Government, made hearings for the visitors to ports and beaches. They were dissatisfied with garbage on the beach and the turbidity of water. Another research on waterfront developments also shows that "purification of organic contaminated water along shore" gets first priority.

These surveys make it clear that citizens expect more comfortable coastal environment, and that the actual condition of the present inner coast near urban areas needs some measurements to purify water. Higher water quality is now required even for "watching." The improved quality is suggested to promote its utilization by citizens as well.

3. Basic concepts for creating comfortable coasts

The sea has its own attractiveness and gives much relief and comfort under well arranged conditions. So as to pull out more attractive and comfortable scenery, we try to follow the five basic concepts for arranging.

1) "encouraging to show natural characteristics of the sea"

The natural characteristics of the sea are, for examples, enormous mass of water, wide open surface, large heat capacity, rich in salts and ions, waves and tides, and various kinds of livings. All of these are impressive for us. We feel relaxed due to its width, the open sky with sea gulls, cool fresh winds, salty smells, regular sounds of waves and shells on a beach.

2) "creating and enhancing good conditions intentionally"

The sea has its potential to attract people in itself. We are trying to help express attractiveness of the sea by managing coastal environment. If bad water quality prevents people from coming closer to the water surface, then port facilities should be designed in a useful way for improving water quality.

3) "making mutual connections between land and sea"

We have been stressing heavily on the prevention from coastal disasters, such as high surges and wave attacks. It often happens that people living near shore can hardly sea the water surface because of highly installed seawalls. The disaster prevention facilities should harmonize with easy access to the sea water. Floating bridges, artificial beaches and off-shore banks could be ideas for improving accessibility.

4) "maintaining water quality suitable for its utilization level"

Water quality indices originally express the degree of inconvenience for a certain utilization. For watching, less turbid and better smell quality is required, which is quite different from that for bathing. Considering utilization of coastal areas will mean to suppose utilizers who enjoy good circumstances. If we can identify persons who should pay for improving environments, we can discuss more easily the cost-benefit relation and financial plan

5) "combining countermeasures economically"

The sewage treatment is one of the powerful countermeasures to reduce the organic pollutant load to the coastal water. For waterfront developments, sewage treatment system is inevitable. But, for maintaining good condition in shallow coasts, the secondary sewage treatment is not sufficient for nutrient removal. Moreover, the water quality along coasts is lower in concentration and larger in water mass than that in sewage effluents and rivers. It is difficult to apply the sewage treatment techniques directly toward coastal water. Here, we consider the treatment techniques other than sewage treatments.

It would be effective to copy purification functions and assimilation activities of the natural coast, which are, for example, filtration at sandy beach, bio-assimilation of organic detritus by shells and settling at coastal wetlands. These activities have seasonal variation in efficiency and are not so tough for the shock loads of high concentration. But, utilization of the natural energies. and of biological activities is economical for us to promote and maintain higher purification ability along coasts. This idea indicates a direction for the research and development on environmental technology. This policy also introduces a management attitude how to increase environmental capacity along coasts.

4. Rearrangement of treatment technologies

Natural purification techniques mentioned above, can be categorized from various points of view. Table-1 is an example list of purification techniques arranged by their principles.

Present ideas and techniques can be arranged in matrix charts. Table-2 is

Table-1 Examples of natural purification techniques

catebory	example	energy
transpot	flow regulation flushing	tide, wave
diffusion	vertical mixing sill	current
degradation	microbial film on rock surface bemthos feeding	organics detritus
assimilation	fish pond lagoon, marsh	organics sunlight
filtration	shells	detritus
settling	reed field, seaweed	gravity

a simple example for the matrix, PRINCIPLES vs. REACTIONS. We can also make another matrix of purification techniques, using PRINCIPLES vs. AVAILABLE NATURAL ENERGIES categories. These matrix will be useful for the combination of individual techniques. We can find out possible ideas applicable for a certain area and similarity among them. The feasible menu of appropriate techniques can be easily considered for each of several geographic, current and water quality conditions of coastal seawater.

5. Programming flow

The programming flow can be drawn like Fig.-1. In Fig.-1, all the feed back lines are not shown. This flow is composed of several steps from the object-setting to the technical-solution, which is followed by the final goal of areal designing. The process of each step is described as follows;
(1) grasping social needs and requests for the assigned coastal area,
(2) research on the natural and social conditions, and present environment,
(3) expressing requests as a catchword (for ex. the sea where we can swim),
(4) making the object clearer by the selection of environmental elements

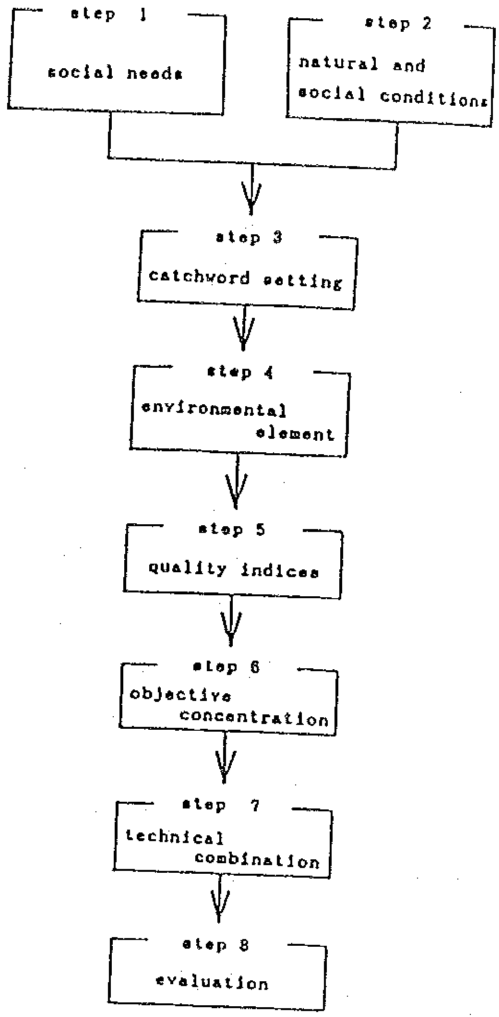


Fig.-1 Programming flow

Table-2 Simple example of matrix

	principles		
reactions	disapper	transformation	transportation
physical reactions	settling	sediment capping	flushing sediment dredging
biological reactions	degradation denitrification	assimilation to biota	cropping, fishing feeding by birds
chemical reactions	oxydation	lime application to sediment	coagulation

(water quality, sediment quality, wave and etc.) which can affect and disturb the requests sensitively,

(5) giving actual indices to the selected environment elements and making them possible to measure (COD, turbidity, coliform and etc. to the water quality),

(6) assigning each index an actual value or concentration which suits the utilization of the water surface (COD <2mg/l, coliform <1000M.P.N., and etc. for swimming level),

(7) choosing and combining technical measures to satisfy the required environmental value or concentration,

(8) evaluating the requested level, techniques and dimensions from the view point of designing feasibility.

6. Case studies

We picked up five areas for case studies in order to get more actual images to the programming flow. Two of the five areas are located at the inner Tokyo Bay, three are along the Mikawa Bay. Both are typical eutrophic bays.

6.1 Ariake area in Tokyo Bay

1) present condition

This area has an abandoned shallow canal which were once used as a main navigation route and stock surface for woods. The canal has two openings at the north-east and the south-west end, and is surrounded by old warehouses and factories. This area is located near the metropolitan area. Water quality is worse in summer (COD §6mg/l, T-P 0.3mg/l) due to the high primary production of plankton. Bad smell by the anaerobic reaction at bottom sediments also keeps people from coming near to the water in summer. Tokyo Metropolitan Government has a rehabilitation plan to construct a high-density residential area.

2)programming flow

We give a catchword of "harmonic symphony between sea and man at urban oasis", which means introducing attractiveness of the sea into the urban area. We select water quality, accessibility, and landscape as important environmental elements to present more comfortable waterfront. Utilization level is set as mainly watching (touching at some part), and COD (Chemical Oxygen Demand) and DO (Dissolved Oxygen) are chosen for representative water-quality indices. We assign objective concentration for these two, as COD <4mg/l and DO >2mg/l.

Areal designing principles are as follows; 1) conserving present water surface (55ha) as wide as possible for open sight and better landscape, 2) keeping old breakwaters as they are because of dense natural woods on them, 3) arranging an artificial beach/marsh along the canal, a pedestrian wall and a bridge over the canal, so as citizens to access water easily.

Fig.-2 shows a zoning plan of this idea. Water surface area is about 46ha, and water volume is roughly 1,000,000m^3.

3)technical consideration

Owing to the very few observation data, we cannot make the accurate estimation of nutrient mass balance in this area. The result of two-layer numerical flow simulation suggests that there exists very little tidal residual flow but a small residual flow due to fresh water effluent from factories. The budget of total phosphorus (T-P) can be guessed roughly from the available data, inflow from the surrounding sea at flood tide 15kg/day, inflow from freshwater effluents = 6kg/day, inflow from the bottom sediment = 6.5kg/day, settling to the bottom sediment = 1.5kg/day. outflow to the surrounding sea - 26kg/day. The greatest nutrient load is evidently the inflow from the surrounding eutrophic sea followed by the release from the sediment.

Technical considerations for the water quality and flow management will be made as follows; 1)dredging organic sediment with sand capping, which is effective to lessen nutrient concentration in this canal due to both its shallowness (mean depth: 2m) and small water exchanging, 2)enclosing the canal water by east and west gates loosely to separate the improved water from surrounding eutrophic water of the inner bay, 3)introducing surrounding water after purification into the canal and making one directional flow (from the east end to the west gate) through the canal to exchange water (hydraulic retention time: 50days), 4)making tidal movement (+-10cm above/below M.S.L.) in the canal to support the biological activity at the artificial marsh, 5) utilizing tidal energy (tidal range for M2 component: 1m) for above 3) and 4) treatments.

Fig.-3 is the schematic map of the water flow with the combination of purification facilities. Applied facilities besides the capping are, 1) artificial seagrass woods in front of the western entrance gate, 2)rock filter waterway under the pedestrian sidewalk, 3)an artificial marsh at the east end. Water mass intake is about 210,000 m^3/day. Total area of the seagrass leaves is 3,200 m^2, expecting 20 or 25% solid separation efficiency. Total length of the rock filter way is set 1.5 km, expecting 60% removal of COD from the experimental result for fresh water[3]. A coagulation process can be applied, if necessary, after the rock filtration (33% removal for COD and SS).

4)evaluation of the effect

Water quality can be evaluated by the numerical simulation by assigning the efficiency of each process. Predicted concentration of COD is presented in Fig.-4 for three options of the combination. Option 1 represents the combination of capping, 20% removal at seagrass woods, and rock filtration. Option 2 expresses capping, 25% removal at seagrass woods, and rock filtration. For Option 3, a coagulation process is added to Option 2 after filtration. The result shows that COD <4mg/l can be attained in this canal. Higher DO above 2mg/l is also calculated for all the options. A conceptual view of this development plan can be drawn like Fig.-5.

6.2 Yokohama inner port in Tokyo Bay

We selected a river mouth at the inner port of Yokohama as a study area. This river has a waste treatment plant at the upper part, and is the dominant pollutant source to the mouth area. This area (13 ha) is now surrounded by wharves and bank walls. Yokohama City has a rehabilitation plan here around and this water surface is expected to be an open space with water affinity.

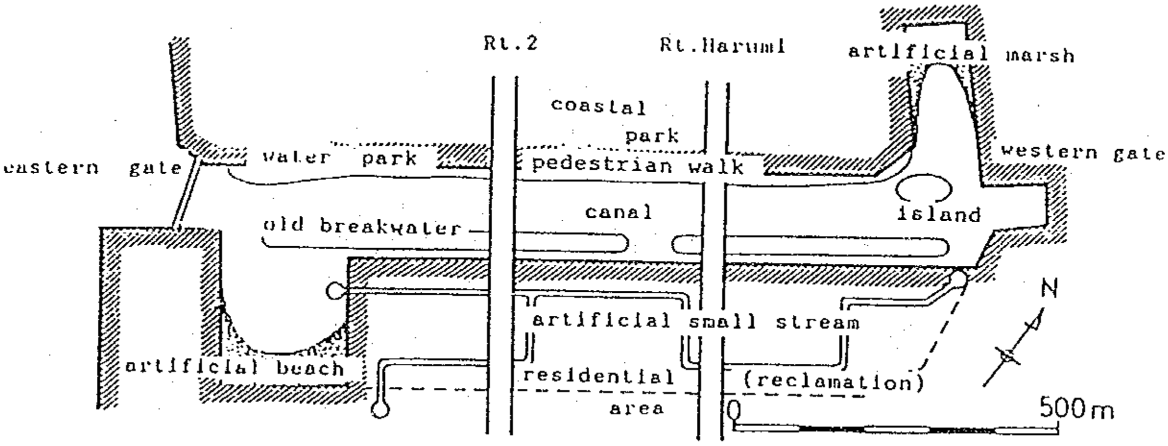


Fig.-2 Zone arrangement of Ariake area

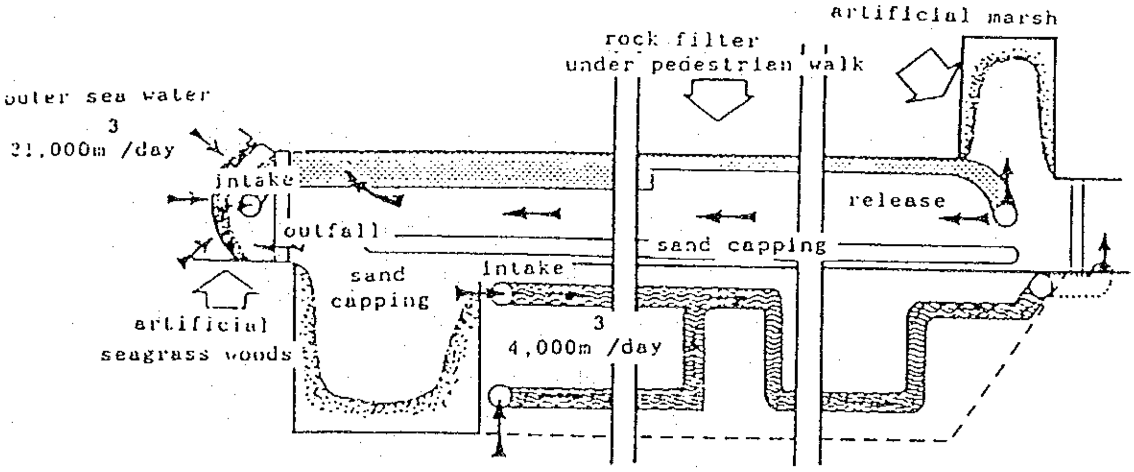
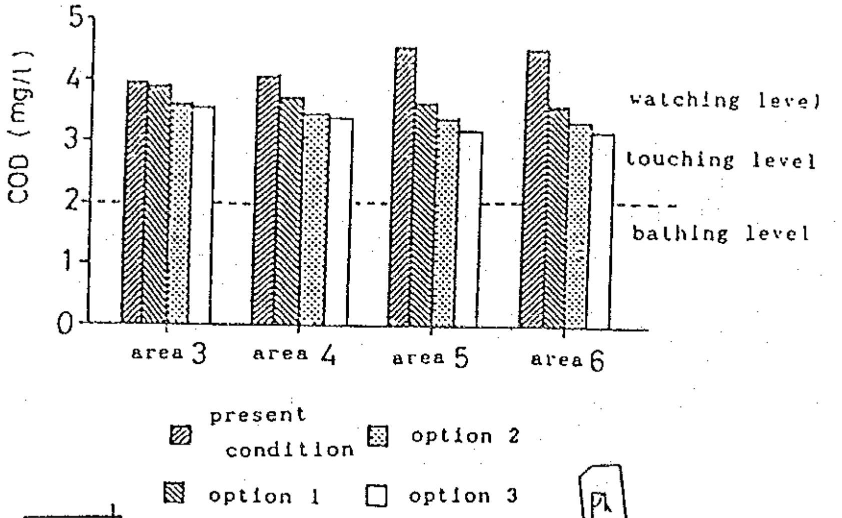


Fig.-3 Schematic map of water flow and purification facilities
(black arrow: water flow, white arrow: facility)



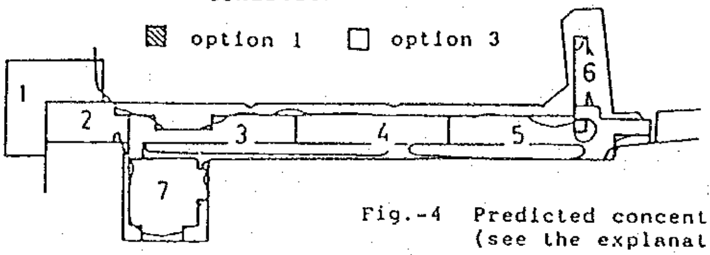


Fig.-4 Predicted concentration of COD in each area (see the explanation of options in the text)

But, in summer, water quality (COD 5-6.5mg/l, transparency 1.7m) is not good enough to be touched. The catchword is "the creation of water affinity in the urban area." The objective use is set as "touching", and transparency is selected for the environmental element. The critical transparency for this level is estimated as 2m.

Dredging and capping is thought effective here, too. COD and DO of the bottom layer off the Port is low even in summer. Another measure is to introduce this bottom water into the river mouth area after aeration by artificial falls. A basic and expensive solution is to lessen the river load. Let us consider two measures, one is partial sand filtration of the river water itself at the upper point, and the other is to change the river flow away from the concerned area. Three kinds of combinations -- (Option 1; capping + introduction of the outer water), (Option 2; Option 1 + river purification), and (Option 3; Option 1 + change of the river route) -- are evaluated by the numerical simulation. 1.8-2.2m of transparency is obtained for Option 1, and above 2.5m for Option 2. Option 3 gives a low quality spot at the neighbor surface and is not fit for our object.

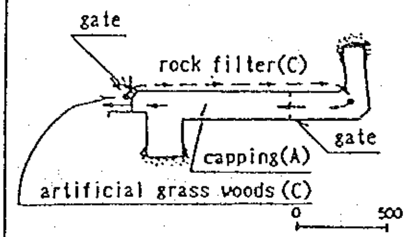
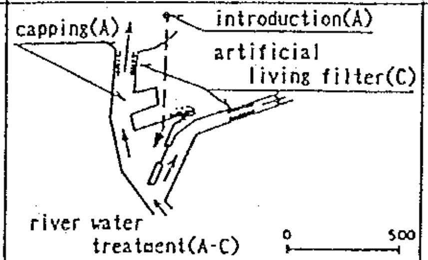
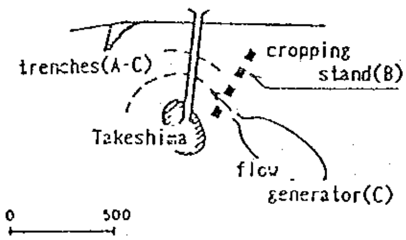
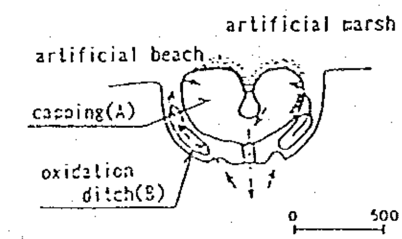
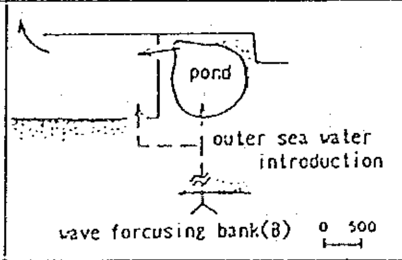
6.3 Takeshima Island in Mikawa Bay

Both Takeshima and Ootuka areas belong to Gamagouri City which is facing to the Mikawa Bay and is very attractive for the mild climate and long shallow coast. Takeshima Island is famous for its beautiful sight and an old shrine on it. Many visitors come to this island and beach. But high seawalls and ripen smell of drifted seaweeds (Aosa, Ulva lactuca) on beaches make visitors unsatisfied. Water quality is good enough for "touching level" at present.

"Come to Gamagouri" is a catchword for both Takeshima and Ootuka. Important environmental elements for the Takeshima area are easy accessibility to the beach, and beach protection from drifting seaweeds. High productivity of seaweeds is a result of eutrophication of the Mikawa Bay. Dredging and capping along the shore is first measure. Flow regulation is expected the most effective for beach protection from seaweeds. A flow generator from tidal energy can be applied off the beach with deepen trenches and jetties for flow regulation. All these facilities will promote one directional flow parallel to the beach. At the mouth of the flow generator, cropping shelves with wire mesh fence will collect drifting weeds. A numerical simulation with drifting markers shows that 80% of the markers which arrive to the beach under the present configuration, are caught at the shelves. Nourishing beach with jetties is decrease seawalls in height.

6.4 Ootuka beach in Mikawa Bay

Table-3 Summary of case studies

area	natural condition	「catchword」 (object level) main attractives	proposed system for environmental improvement (A~D: technical feasibility)	environmental facilities area/cost (ha)(10^8 YEN)	water quality improvement
Ariake	eutrophic canals	「harmonic symphony」 (watching) side walk, water park		83 / 89	COD(mg/l) 4~6.2 → 3.2~3.8 DO (mg/l) 1.4~7 → 3.3~8.8 transparency → 1.8m
Yokohama	river mouth	「water affinity」 (watching) side walk, boating		13 / 68	COD(mg/l) 5~6.5 → 4 DO (mg/l) 4~8 → 7.0 transparency 1.7m → 1.8~2.5m
Takeshima	open beach	「Come to Gamagouri」 (touching) shell hunting Takesima Shrine		60 / 35	80% of drifting grass is removed
Ootsuka	high seawalls	(bathing) bathing beach		33 / 73	COD(mg/l) 3.4~4.9 → ~2 DO (mg/l) 6.1~9.6 → 7.5~ transparency → 2.5~3m
Tahara	easy to introduce outer sea water	「resort developing」 (bathing) bathing, pond		790 / 220	COD(mg/l) 4~ → 2.7~3.6 DO (mg/l) ~4 → 6.5~7 transparency → 2~2.5m

For this area, we set another goal to arrange a bathing beach with "bathing level" water quality. We can hardly find bathing beaches along this coast. A new bathing beach here is expected to increase visitors in number. Representative environmental elements are COD of water quality, and accessibility to beach in harmony with the disaster prevention from high surge. COD 2mg/l is set as the objective concentration.

Present water quality is COD 3mg/l in summer and a little different from the objective concentration. Then, the bathing area with artificial beaches is designed to be enclosed by an off-shore bank. This bank will have a wide crown for a pedestrian walk and water purification ditches. The tide makes head difference between outer sea and the bathing area. At the flood tide, water from outer sea will be introduced into the bathing area through ditches. The ebb tide makes the bathing water flow out through a submerged gate. Hydraulic retention time for this system is estimated as one week, Tidal range inside is also estimated 30% as high as that at the outer sea. Numerical simulation shows that the effect of the purification ditches is not enough to satisfy the objective goal. We need associated capping on the bathing area and some ecological help on a sand beach to gain the high quality of COD <2mg/l.

6.5 Tahara area in Mikawa Bay

Tahara area is located on the Atsumi Peninsula which separate the Mikawa Bay and the Pacific Ocean. This area has a long beach (1km) facing to the Mikawa Bay. Water quality in summer is COD 3-4mg/l which is not suitable for bathing. Our goal is set to create bathing environment (COD <2mg/l) for wide water surface (L=1km and W=500m). At the Pacific Ocean side, we have much clearer water (COD 1-1.5mg/l) and enough wave energy (Hmean =0.84m). Using this wave energy, water introduction from the Ocean is planned. Waves (H >1m) will be collected by a shore slope to get higher elevation (+3m). The outer water is going down across the Peninsula (6500m) to the receiving pond in the Tahara area. If the flow of $7m^3$/sec is attained, water quality in the bathing area becomes COD 1.5mg/l. The change of salinity concentration is estimated small. Total effect to the whole Mikawa bay is still left unknown.

7. Conclusions

1) Economical point of view

We tried to estimate the required cost for the construction of purification facilities at each case study area. Results are shown in Table-3 with natural and social conditions together. Our programming flow can be applied for various conditions. Comparing the results, we can find it more expensive to improve worse quality of wider area, as expected. Each plan should be evaluated again from the economical point.

2) Technical objects

In Table-3, main facilities for environmental improvement are also summarized with each technical feasibility (from A: available right now, to D: maybe available in the future). Among various ideas, we can point out the importance of the coastal eco-technology including the utilization of microbial activity, and the flow regulation technology. Rules for the suitable combination of elemental facilities are also essential.

3) Environmental management

Our numerical study[4] has already shown that changes of the coastal features in an enclosed eutrophic bay affects the water quality near and off the coast. A coastal chain of the waterfront treatments for the environmental improvement will make a good effect on the water quality of the whole bay. This effect will be estimated as an increase of the environmental assimilation capacity of the bay.

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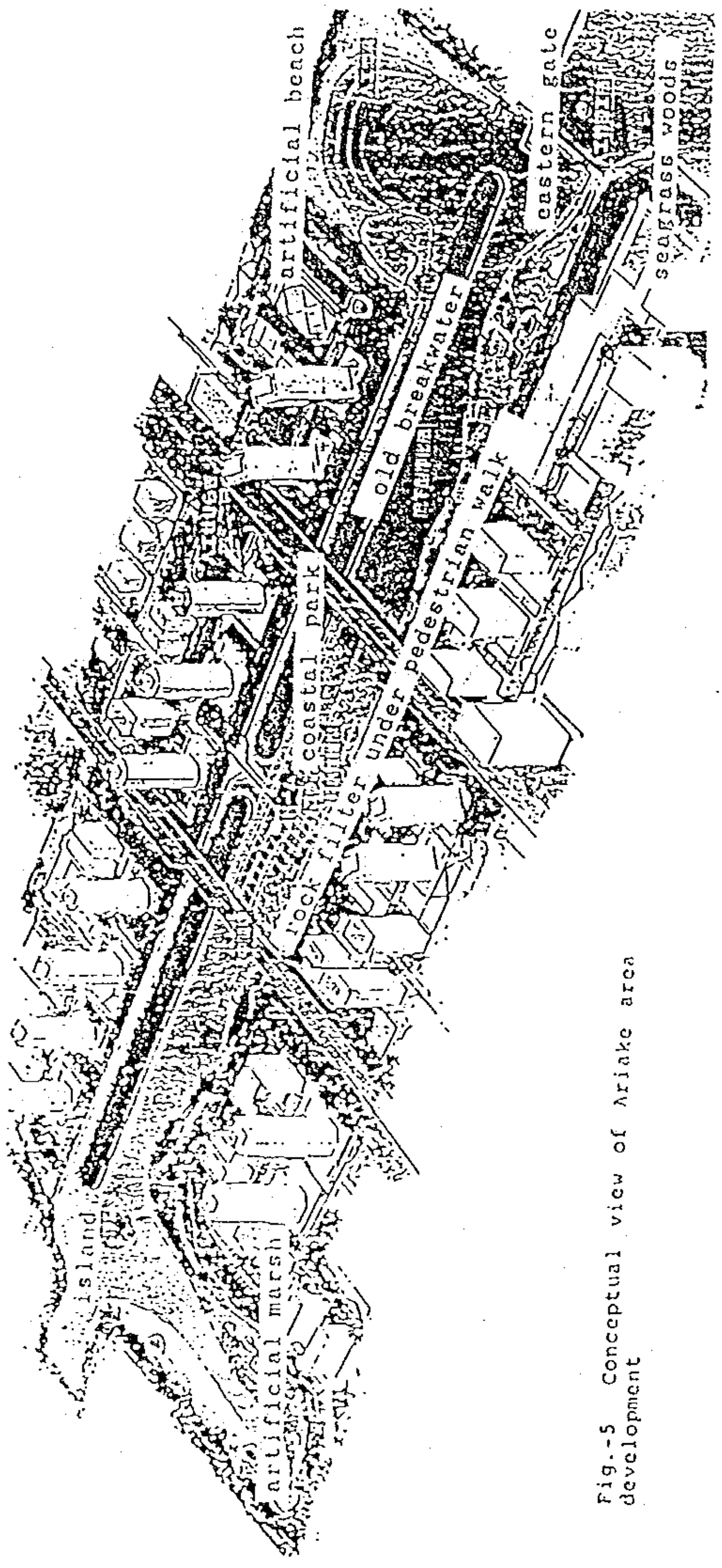

Fig.-5 Conceptual view of Ariake area development

Table 1 A History of Japanese Efforts to Preserve Water Quality

FY	Event
1891	The Ashio Copper Mine issue was discussed at the Diet session.
1897	An Ashio Copper Mine Pollution Investigation Group was organized.
1949	The Mine Safety Law was enacted.
	Tokyo Metropolitan Regulations to Control Factory Pollution were issued.
1956	Minamata Health Center discoverd a "strange disease".
1958	The Water Quality Conservation Law and the Factory Effluent Control Law were enacted.
	The Sewerage Law was also enacted.
1961	Offensive odor from fish on and off the Coaset of Mizushima become an issue.
1965	The Special Commitee for Environmental Pollution Control was established in both the Upper and Lower Houses.
	There was a second occurrence of Minamata disease along Agano river.
1967	The Basic Law for Environmenatl Pollution Control was enacted.
1970	The Headquarters for Countermeasures for Environmental Pollution was set up.
	Environmental Quality Standards relating to water pollution were established at a cabinet meeting.
	The Basic Low for Environmental Pollution Control etc. were amended (at the "Pollution Diet").
1971	The Environment Agency was inaugurated.
	The Central Council on Environmental Pollution Control was established.
1972	A large-scale red tide in Seto Inland Sea damaged fishery products.
	The absolute liability was introduced (Water Pollution Control Law amendent).
1973	The Interim Law for Conservation of the Environment of the Seto Inland Sea was enacted.
1977	Large-scale red tide was observed in the sea of Harima in the Seto Inland Sea.
1978	The Basic Plan for Conservation of the Environment of the Seto Inland Sea was approved at a cabinet meeting.
	The Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea was enacted.
	An areawide total water pollutant load control was institutionalized (an amendent of the Water Pollution Control Law).
1979	An areawide total pollutant load control was enforced in Tokyo Bay, Ise Bay, and the Seto Inland Sea.
1980	Selfcontrol for using detergent containing phosphorus was requested.
1983	The Law Relating to the Prevention of Marine Pllution and Maritime Disaster was amended.
1984	The Law Concerning Special Measures for the Preservation of Lake Water Quality was enacted.
1985	Nitrogen and Phosphorus control standards relating to lakes and reservoirs were established.
1986	The second areawide total pollutant load control was enforced.
1989	Control standards for trichloroethylene and tetrachloroethylene were established.
	Preventive measures against groundwater pollution were institutionalized (an amendment of the Water Pollution Control Law).
1990	Measures against domestic effluent were institutionalized (an amendent of the Water Pllution Control Law).