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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY

INTERNATIONAL INSTITUTE FOR EARTH, ENVIRONMENTAL AND MARINE SCIENCES AND TECHNOLOGIES

VENICE INTERNATIONAL CENTRE FOR MARINE SCIENCES AND TECHNOLOGIES

International Course on Coastal Zone Management

19-30 October 1992

Villa Duodo, Monselice - Italy

Final Report

TECHWARE, Brussels, Belgium

"DINO TONINI" INTERNATIONAL CENTRE OF HYDROLOGY
UNIVERSITY OF PADUA - Italy

CONTENTS

International Course on Coastal Zone Management

International Course on Coastal Zone Management

Part 1– Final Report

Final Report

Enrico Feoli

Deputy Coordinator
International Institute for Earth, Environmental
and Marine Sciences and Technologies - IIEM

Introduction

This is the first of a series of International Courses on Coastal Management, which will be organized on a yearly basis by the International Centre for Science and High Technology. The purpose of these Courses will be to introduce scientists from developing countries to various aspects on the management of coastal areas, both in economic, legislative and environmental points of view. These Courses will help coastal communities to plan sustained development of the coastal economy, reducing environmental risks and hazards.

The International Course on Coastal Zone Management was held in Monselice where the International Centre for Hydrology is situated. The Centre is part of the University of Padua, with which the ICS has a sustained collaboration, in fact, a considerable support towards the Course was given by various professors and assistants from this University.

The Course was divided into four different sections lasting 10 days for a total of 34 lecturers giving about 2 lecture hours each.

Coastal Environment

The lectures were dealing with water movement in the sea and inlets. Particular attention was given to sea-level variations owing to global warming. Salinity and sedimentation were considered in connection with biological resources, while coastal morphology and dynamics were considered in connection with coastal protection. Ecology of coastal waters was a topic developed in two lectures and a seminar discussion, examples of trophic nets under different pollution conditions had been illustrated.

Land and Water Uses

Lectures of this section presented many case studies of heavy industrialized and urbanized coasts, and examples of engineering solutions for efficient management of coastal environment. Problem such as pollution and environmental hazards had been described under the perspective of reducing the risk of catastrophic events. The effects of agriculture, fisheries, acquaculture and recreation were illustrated and proposals for reducing the environmental impact were presented. Particularattention was paid to the problem of dredging and disposal of dredged material. Case studies were illustrated from the Netherlands and the Venice lagoon.

Management Tools

The lectures dealt with Geographical Information Systems and the necessary integration of information for coastal zone management.
Several computer demonstrations on this topic and practical exercises on how to build an expert system have been also given.
The principles on maritime law were discussed at the light of agenda 21 of the Rio Conference.

Impact Analyses

Various procedures for drafting an environmental impact statement were illustrated in theoretical lectures, and studies of social impact of coastal zone projects were exemplified by discussing real case studies.

A field trip to visit the river mouths along the venetian coast was hosted by the Consorzio Venezia Nuova, with a prior presentation of Dr. F. Bandarin on the subject. The itinerary consisted in a short video introduction and subsequently on a long tour via motorboat around Venice to see the mouths. All participants attended enthusiastically.
For this purpose specific cases were considered and information methods were applied for supporting decisions (expert systems, geographic information systems, data banks, etc.). The students had the occasion to work directly on computers and to test the effects of different choices in coastal management of their countries.

International Course on Coastal Zone Management

Part 2– Programme

INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY

VENICE CENTRE FOR MARINE SCIENCES AND TECHNOLOGIES

International Course on Coastal Zone Management

19-30 October 1992
Villa Duodo, Monselice, Italy

Programme

Monday, 19 October

9:30	*Welcoming address* Augusto Forti ICS Project Leader
9:40	Giampaolo Di Silvio Director, International Institute of Hydrology
9:50	Enrico Feoli IIEM Local Coordinator
9:55	Sergio Fattorelli Course Co-Director
10:00	**Coffee Break and Registration**
10:30	*Opening Session* Louis Mostertman Course Co-Director
11:30	*River-Ocean-Interaction: Salinity and Sedimentation* Giampaolo Di Silvio
12:30	**Lunch Break**
14:30	*Waves and Currents in the Coastal Zone* Alberto Lamberti
16:00	*Coastal Processes and Protection (Functional Aspects)* Gianfranco Liberatore

Tuesday, 20 October

9:00	*Coastal Conservation and Protection* Van Dijk
10:00	**Coffee Break**
10:30	*Sea Level Variations* Giampietro Puppi
11:30	*Coastal Protection (Structural Aspects)* Leopoldo Franco
12:30	**Lunch Break**
14:30	*Coastal Protection* Leopoldo Franco
15:30	*Video on Coastal Management in The Netherlands* Van Dijk
16:00	*Presentation of the Use of Geographical Information System (G.I.S.) with the Management of the Dutch Wadden Sea* Van Dijk

Wednesday, 21 October

9:00	*Some Aspects of the Lagoon Ecosystem* Oscar Ravera
10:30	**Coffee Break**
11:00	*Morphology and Dynamics of the Beaches and of the Littoral Zone* Giorgio Tunis
12:30	**Lunch Break**
14:30	*Plankton Production and Trophic Interactions* Alenka Malej
16:00	*Discussion Group: Biological Aspects of the Lagoon Research* Oscar Ravera

Thursday, 22 October

9:00	*Tides* Mostertman
10:30	**Coffee Break**
11:00	*Recreation* Francesco Bandarin
12:30	**Lunch Break**
14:30	Participants' presentation of their case studies

Friday, 23 October Field trip to Venice

Saturday, 24 October

9:00	*Hydraulic Effects of Agricultural Practice* Mario Lenzi
10:30	**Coffee Break**
11:00	*The Relationship between Capture Fisheries and the Environment* A.D. Insull
12:00	**Lunch Break**
14:00	*The Relationship between Aquaculture and the Environment* A.D. Insull
15:00	*Seminar*: Follow-up Actions by FAO to UNCED, Agenda 21, Chapter 17, Programme Area A, Integrated management and sustainable development of coastal and marine areas, including exclusive economic zones. A.D. Insull

Monday, 26 October

9:00	*Dredging* Jan De Koning
10:30	**Coffee Break**
11:00	*Dredging* Jan De Koning
12:30	**Lunch Break**
14:30	*G.I.S. and Model Integration in Coastal Management* Kurt Fedra
15:30	*Disposal of Dredged Material* Jan De Koning

Tuesday, 27 October

9:00	*Reclamation of Industrial Sites* Jan De Koning
10:30	**Coffee Break**
11:00	*Principles of Maritime Law* Adalberto Vallega
12:30	**Lunch Break**
14:30	*Principles of Maritime Law* Adalberto Vallega
16:00	Discussion Group

Wednesday, 28 October

9:00	*Models, G.I.S. and Expert Systems for Environmental Impcct Assessment* Kurt Fedra
10:30	**Coffee Break**
11:00	*Practical exercises with the expert system / Discussion group on Environmental Impact Assessment* Kurt Fedra
12:30	**Lunch Break**
14:30	*Industry and Urbanization* Zanetto

Thursday, 29 October

9:00	*Water Management in Coastal Areas* Louis Mostertman
10:30	**Coffee Break**
11:00	*Italian Legislation and its Enforcements* Antonio Tamburrino
12:30	**Lunch Break**
14:30	*Italian Legislation and its Enforcements* Antonio Tamburrino
16:00	*Management of Tidal and Non-tidal Rivers* Louis Mostertman

Friday, 30 October

9:00	*Human Health and Safety Impact Assessment of Coastal Zone Management* Eric Giroult
10:00	**Coffee Break**
10:30	*Procedures for Drafting and Environmental Impact Statement* Elliot Laniado
11:30	*Human Health and Safety Impact Assessment of Coastal Zone Management* Eric Giroult
12:30	**Lunch Break**
14:30	*Procedures for Drafting and Environmental Impact Statement* Elliot Laniado
16:00	*Concluding Remarks* Louis Mostertman

International Course on Coastal Zone Management

Part 3– List of Participants

International Course on Coastal Zone Management

19-30 October 1992
Villa Duodo, Monselice, Italy

LIST OF PARTICIPANTS

Francesco Bandarin	CL	Consorzio Venezia Nuova Palazzo Morosini San Marco 2803 30124 Venezia	Italy
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CD - Course Director
CL - Course Lecturer
CP - Course Participant
IG - Invited Guest
LO - Local Organizer

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International Course on
Coastal Zone Management

Part 4– Lecture Notes

Giampietro Di Silvio

Università di Padova

RIVER-OCEAN INTERACTIONS:

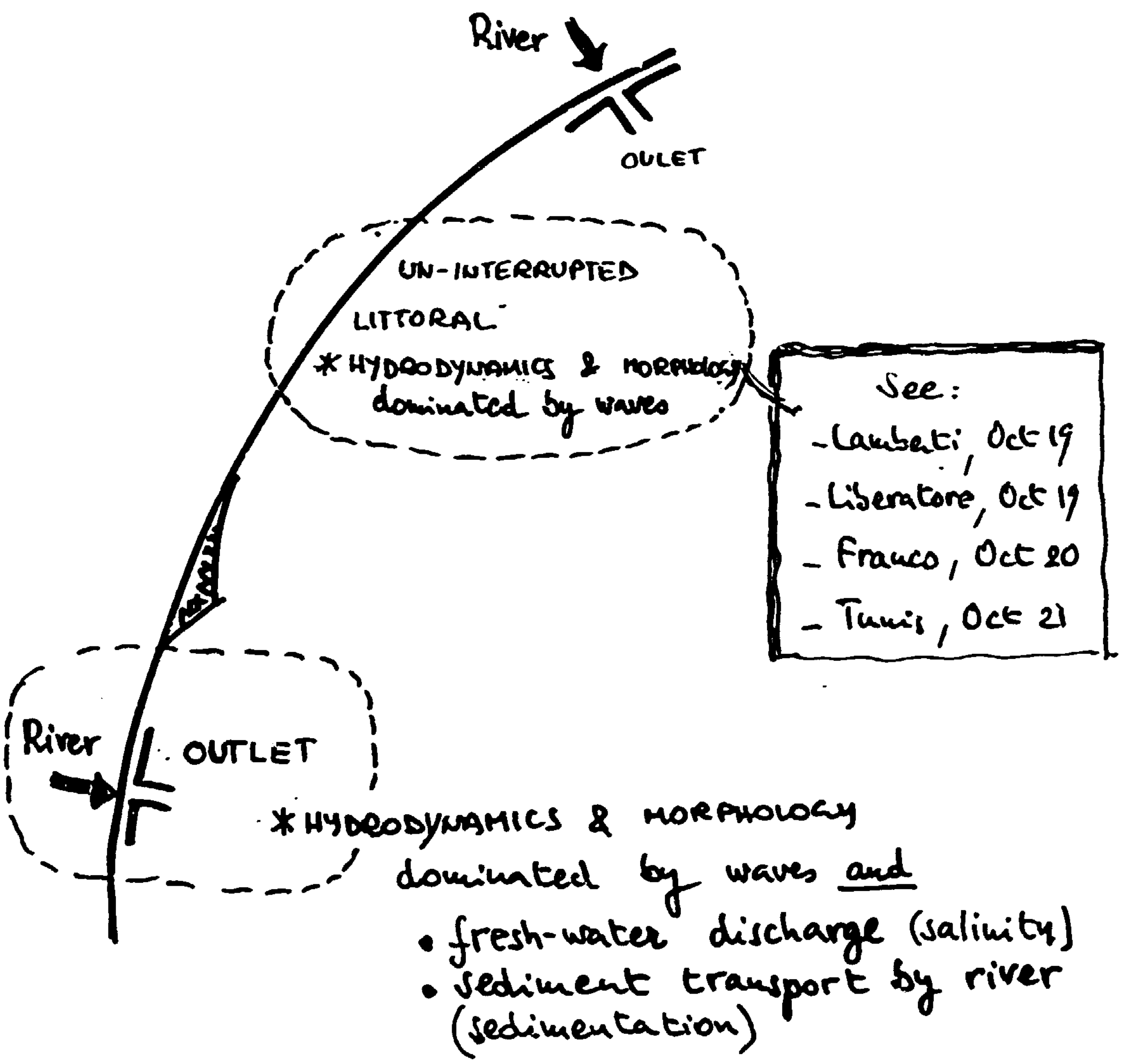
SALINITY & SEDIMENTATION

INTERNATIONAL COURSE ON COASTAL ZONE MANAGEMENT

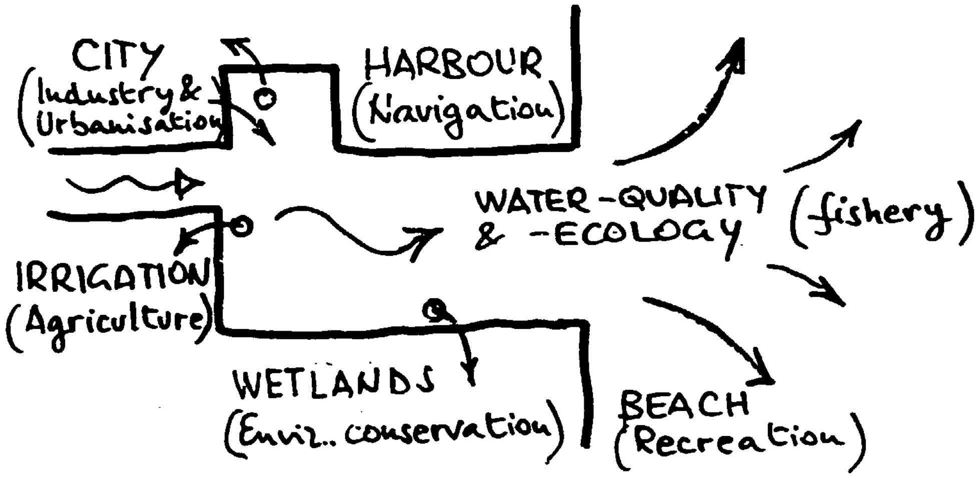
RIVER - OCEAN INTERACTIONS : SALINITY & SEDIMENTATION

G. Di Silvio
University of Padua,
Italy

DYNAMICS AND MORPHOLOGY OF THE COASTAL ZONE - GENERALS



MANAGEMENT IMPLICATIONS OF SALINITY & SEDIMENTATION PROBLEMS

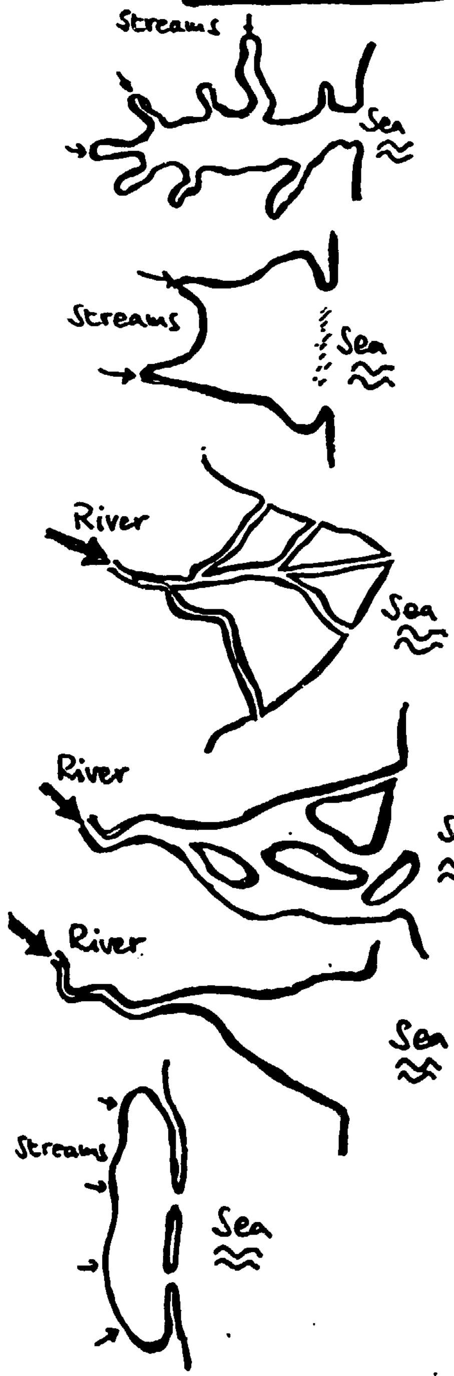


* REQUIRED INFORMATION:

- Waterflow (depth and velocity);
- Space- and time-distribution of salinity, temperature, turbidity, BOD, DO, nutrients, pollutants .....
- Erosion and deposition processes

► WATERFLOW MODEL, TRANSPORT-DISPERSION MODEL, MORPHOLOGICAL MODEL

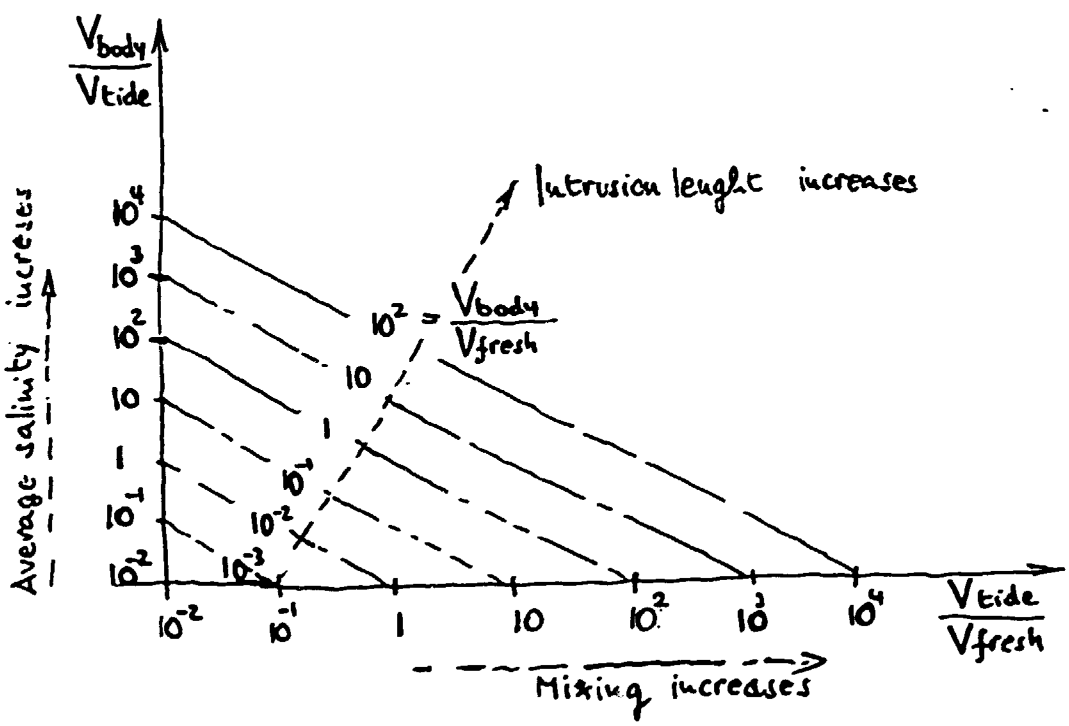
MAIN TYPES OF RIVER OUTLETS



1. FIORDS : Norwege, South. Chile, New Zealand; East. Adriatic
2. LITTORAL INLETS East. U.S., West. Australia...
3. DELTAS : Nile, Niger, Mississippi, Orinoco....
4. TIDAL DELTAS : Gange, Yang-tse, East. Schelde,
5. ESTUARIES : Thames, Severn, Elbe, St. Laurence...
6. TIDAL LAGOONS : Venice, Wadden Sea, German coast,

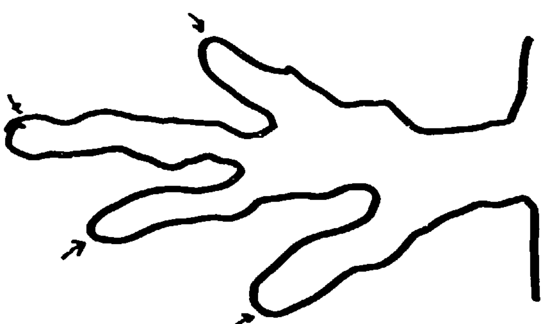
CLASSIFICATION OF RIVER OUTLETS BASED ON DENSITY DIFFERENCES (Pickart 1961, Pritchard 1967)

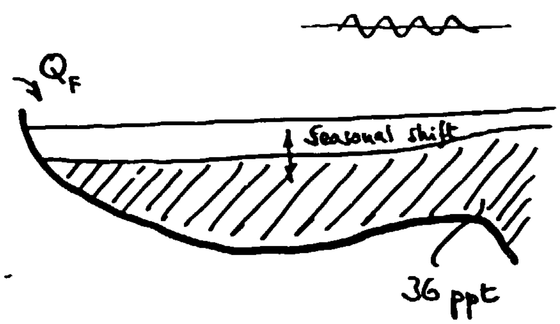
- Tidal Volume V_{tide} = Surface × tidal range
- Freshwater Volume $V_{fresh} = Q_F \times T_{tide}/2$
- Waterbody Volume V_{body} = Surface × av. depth



GEOMETRICAL AND HYDRAULIC CHARACTERISTICS OF RIVER OUTLETS

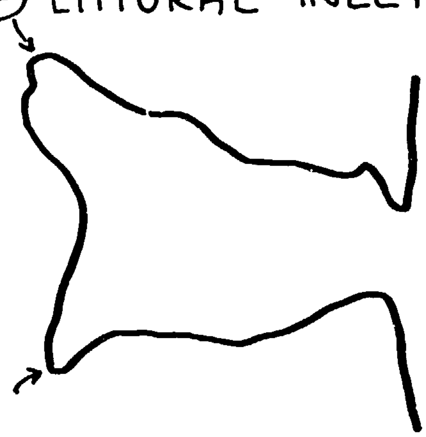
① FIORD

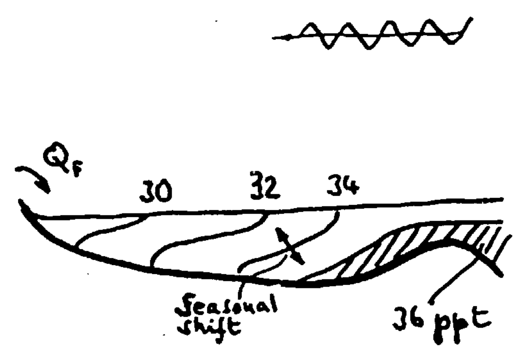




$\frac{V_{tide}}{V_{fresh}} = 0.1 - 1$ $\frac{V_{body}}{V_{tide}} = 100 - 1000$ $\frac{V_{body}}{V_{fresh}} = 10 - 1000$

② LITTORAL INLET

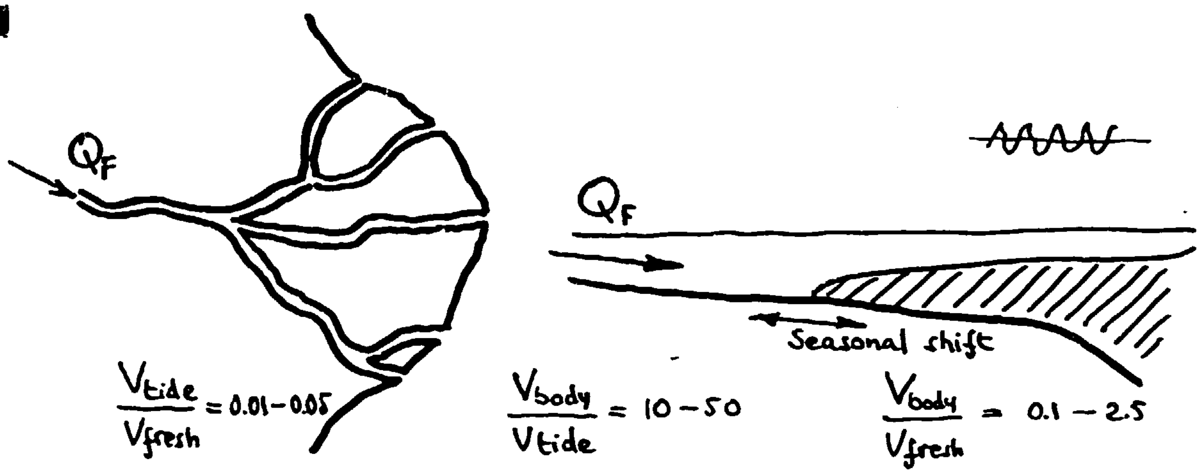




$\frac{V_{tide}}{V_{fresh}} = 0.05 - 0.5$ $\frac{V_{body}}{V_{tide}} = 2 - 50$ $\frac{V_{body}}{V_{fresh}} = 0.1 - 20$

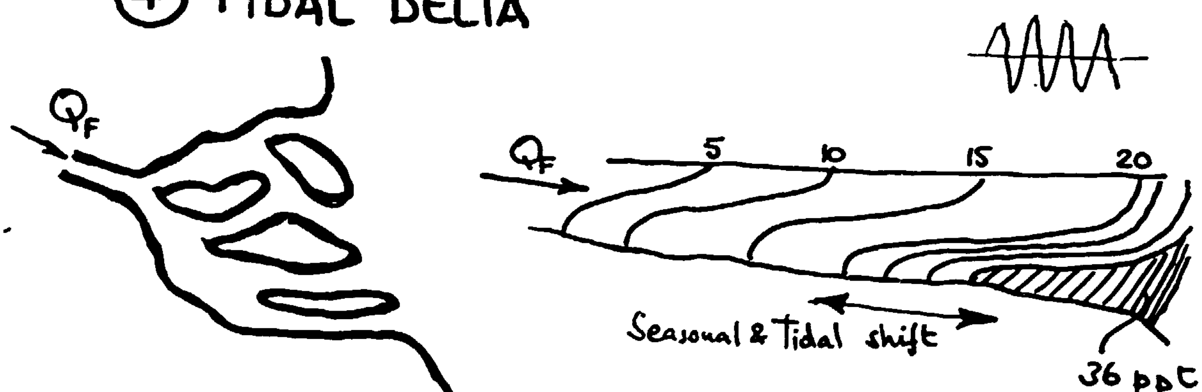
GEOMETRICAL AND HYDRAULIC CHARACTERICS OF RIVER OUTLETS

(3) DELTA



$$\frac{V_{tide}}{V_{fresh}} = 0.01 - 0.05 \qquad \frac{V_{body}}{V_{tide}} = 10 - 50 \qquad \frac{V_{body}}{V_{fresh}} = 0.1 - 2.5$$

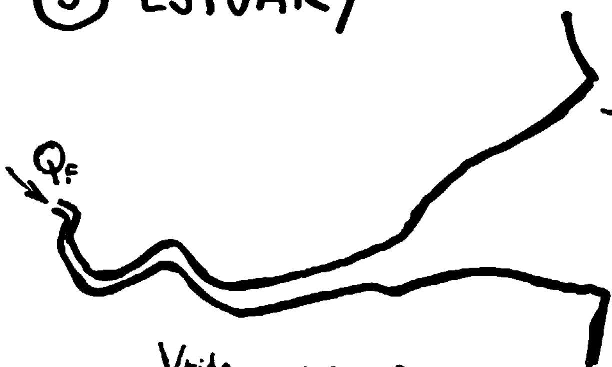
(4) TIDAL DELTA

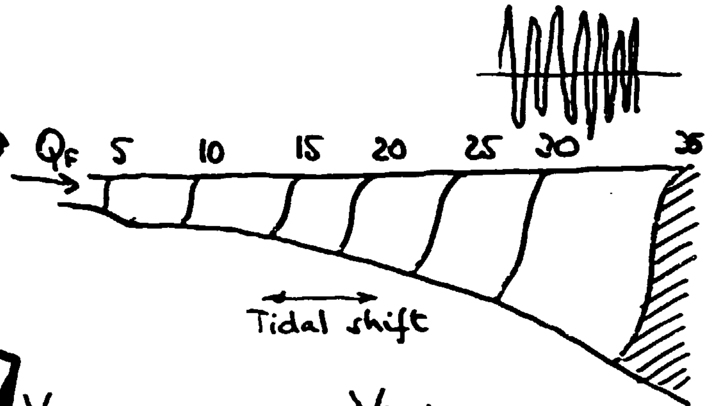


$$\frac{V_{tide}}{V_{fresh}} = 0.05 - 0.5 \qquad \frac{V_{body}}{V_{tide}} = 5 - 10 \qquad \frac{V_{body}}{V_{fresh}} = 0.25 - 5$$

GEOMETRICAL AND HYDRAULIC CHARACTERISTICS OF RIVER OUTLETS

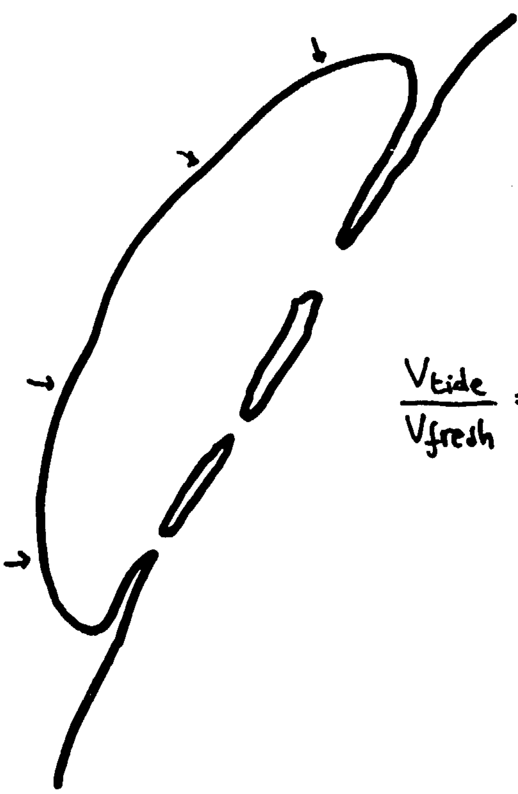
(5) ESTUARY

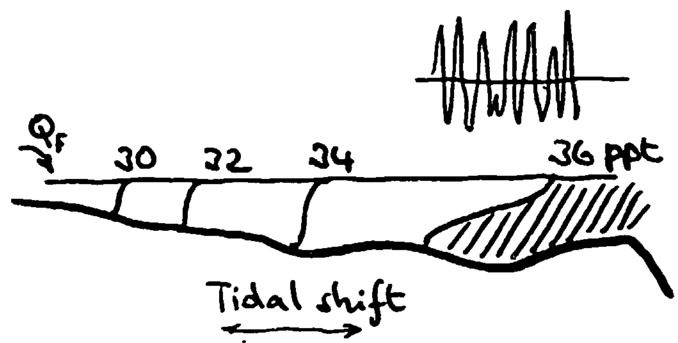




$\frac{V_{tide}}{V_{fresh}} = 0.5 - 2$ $\qquad \frac{V_{body}}{V_{tide}} = 50 - 100$ $\qquad \frac{V_{body}}{V_{fresh}} = 25 - 200$

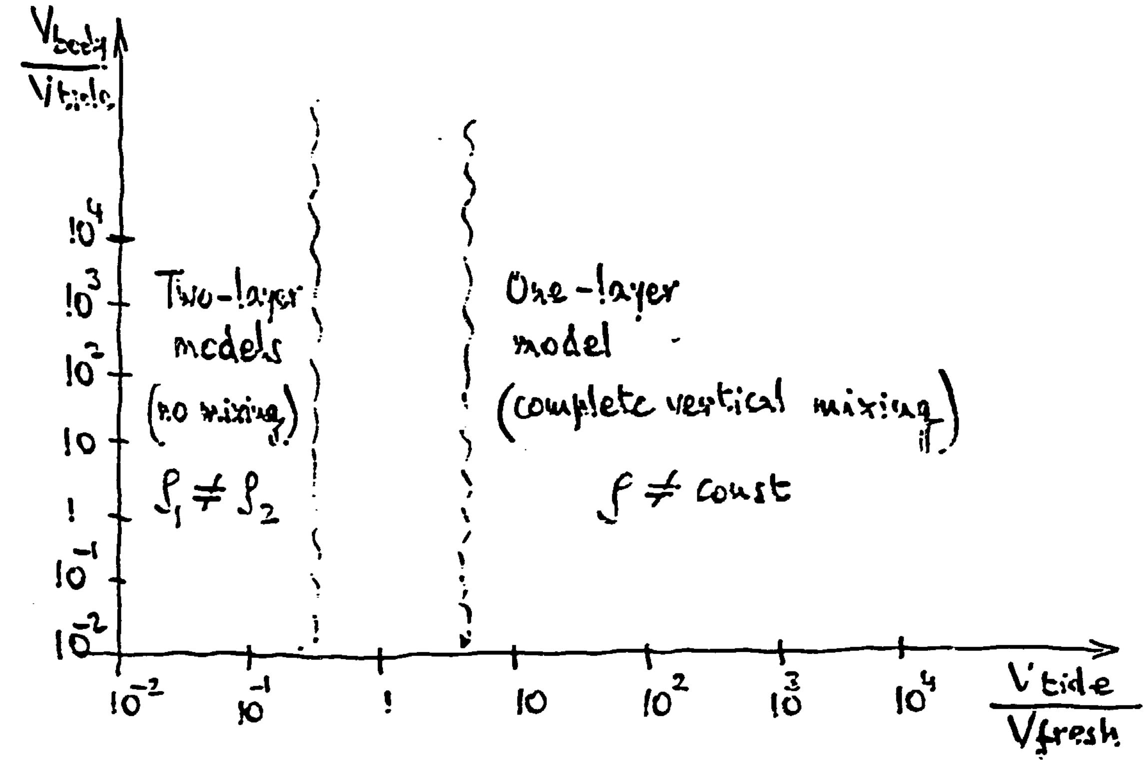
(6) TIDAL LAGOON

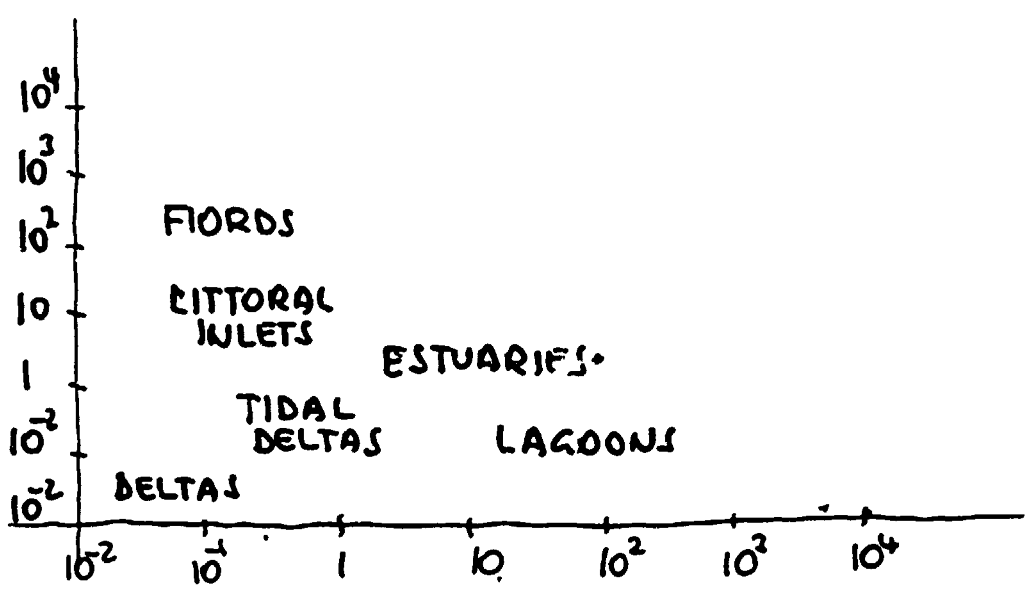




$\frac{V_{tide}}{V_{fresh}} = 50 \div 500$; $\frac{V_{body}}{V_{tide}} = 0.5 - 1$; $\frac{V_{body}}{V_{fresh}} = 25 - 500$

CLASSIFICATION OF RIVER OUTLETS (below)
AND WATERFLOW MODELING (above)





SOME EXAMPLES OF MODEL APPLICATION FOR RIVER-OUTLET MANAGEMENT

1) TIDAL DELTA of R. ADIGE (Stratified flow)

PROBLEM	MODEL
• Change of salt-intrusion lenght due to a reduction of waterflow (statistical analysis)	• 1-DIM, two-layer, unsteady-flow model
• Change of bottom elevation due to a variation of salt intrusion (as above)	• 1-DIM, two-layer long-term, deposition model
• Change of salinity-plume configuration due to the construction of jetties at the river mouth.	• 2-DIM, two-layer steady-flow model

SOME EXEMPLES OF MODEL APPLICATION FOR RIVER-OUTLET MANAGEMENT

2) TIDAL LAGOON OF VENICE (Vertically mixed)

PROBLEM	MODEL
• Change of flow velocity and water elevation due to the construction of surge-barriers.	• 2-DIM, one-layer, unsteady-flow, tidal model
• Change of space- and time-distribution of conservative tracers (e.g. salinity) as above	• 2-DIM, one-layer, unstedy-flow, transport-dispersion model
• Change of long-term morphology of the lagoon due to anthropic action from XV century to present	• 2-DIM, one-layer, long-term, morphological model

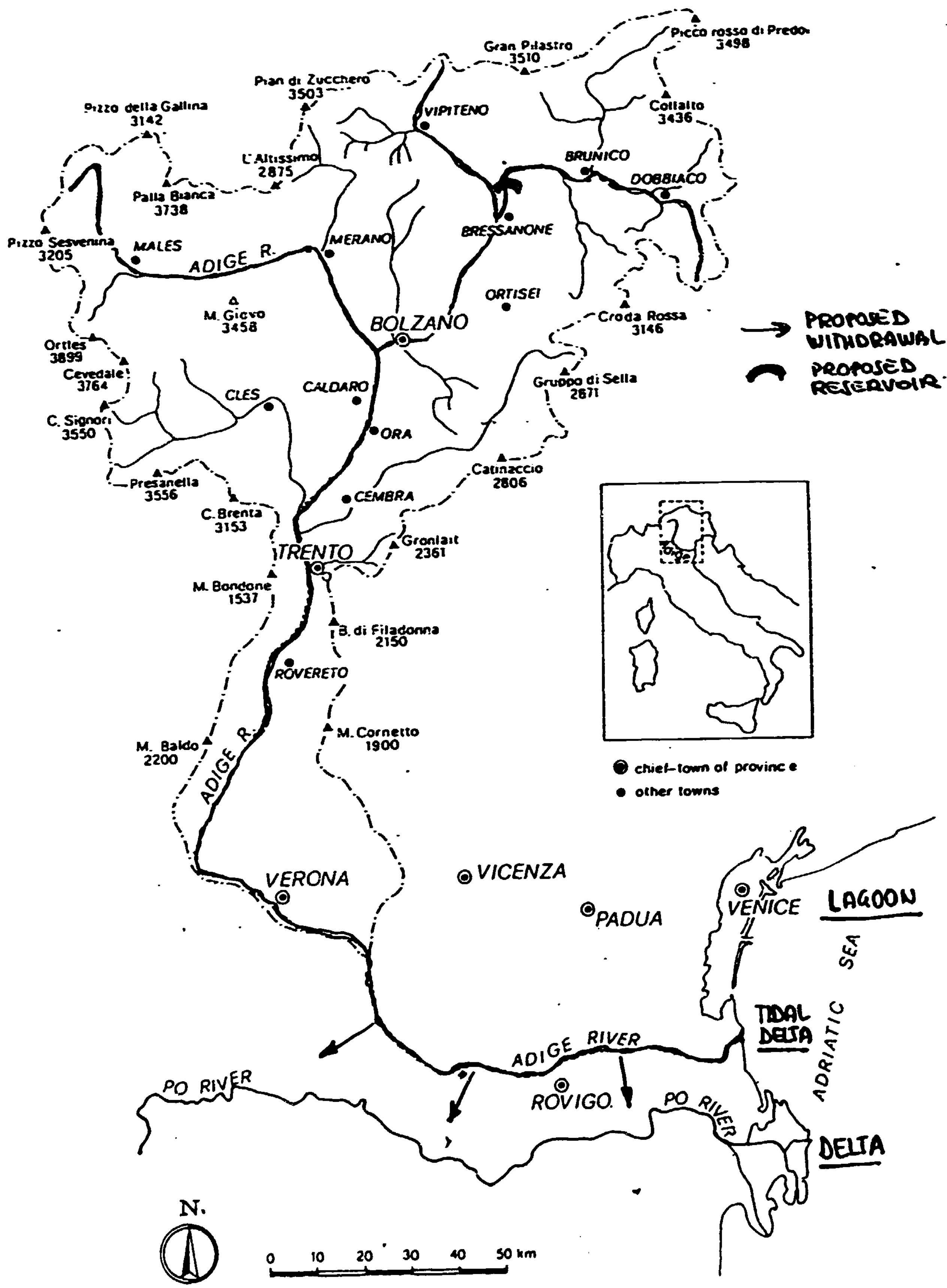
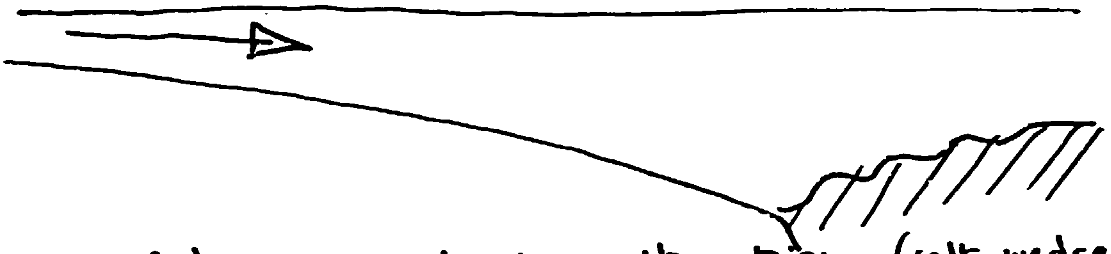


Fig. 1 - Hydrographic basin of the Adige River

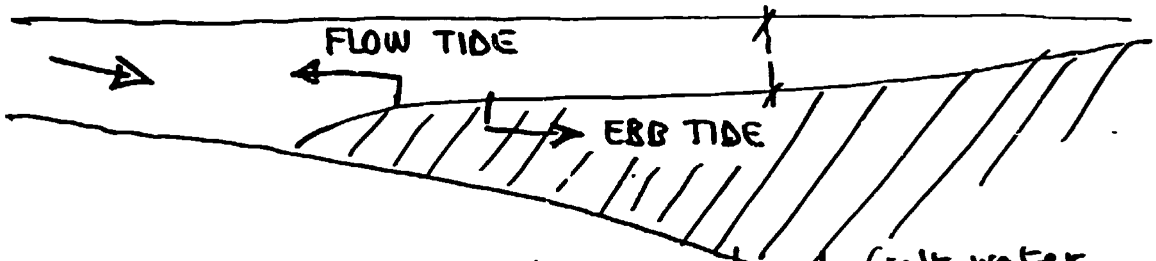
KZ 015

CHANGE OF SALT-INTRUSION LENGHT

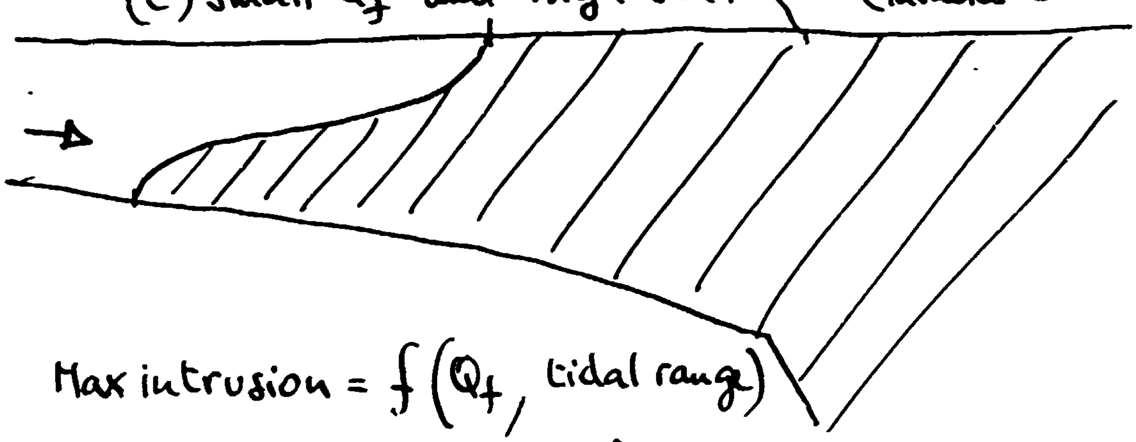
(a) large Q_f and low sealevel (salt-wedge driven back into the sea)



(b) intermediate situation (salt-wedge intrusion)



(c) small Q_f and high sealevel (salt water invades the river)



Max intrusion = $f(Q_f$, tidal range$)$

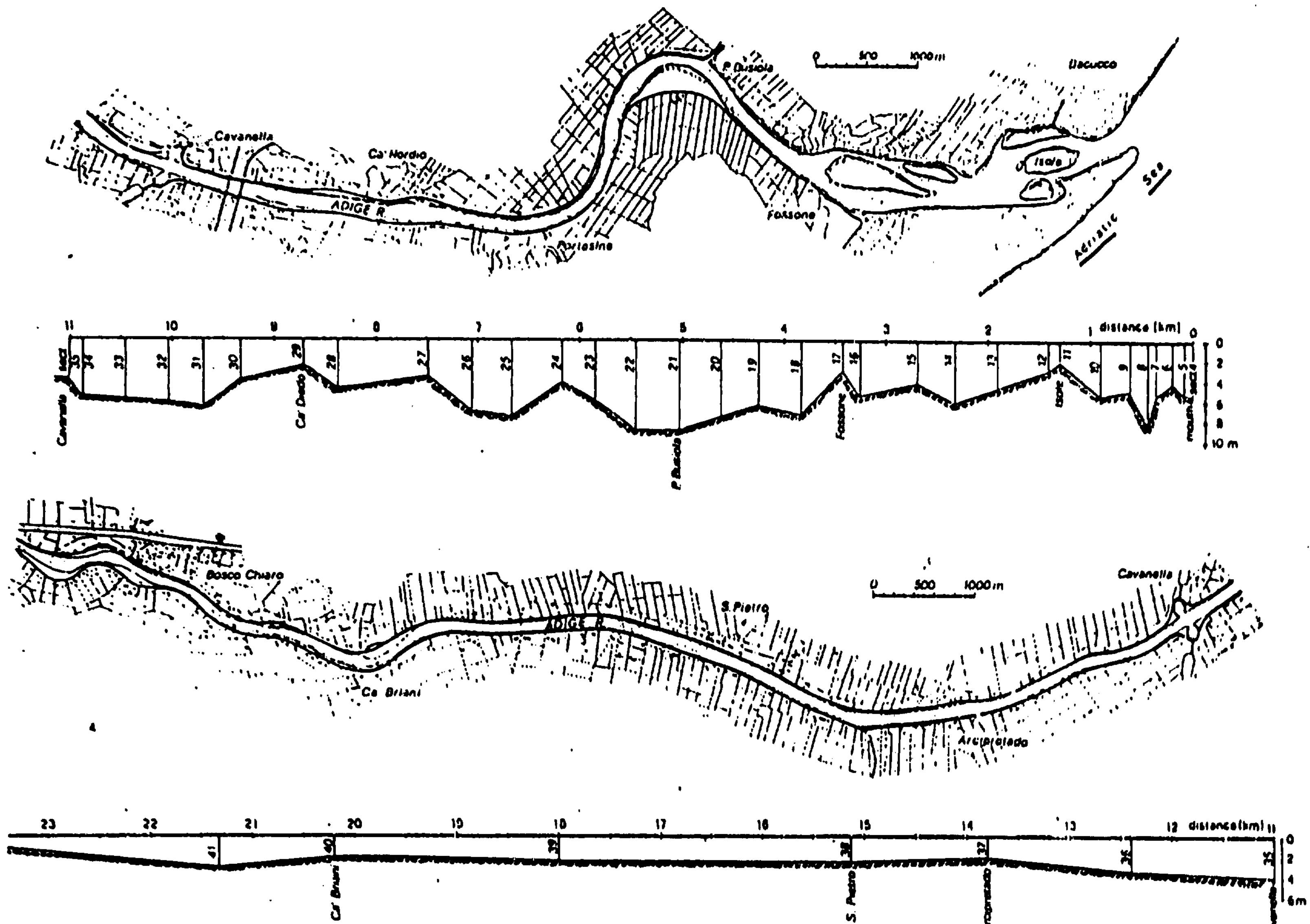


Fig. 2 - Morphological characteristics of the lower part of the Adige. The cross sections shown in the figure have been reproduced on the model.

3. - Calibration of the mathematical model

The lowest part of the Adige River has a rather irregular morphology: its mean depth ranges between 2 and 4 m, and its width between 100 and 300 m. About 40 cross sections (more and more closely distributed toward the mouth) have been used for an accurate geometrical description of a 26 km long reach of the river (Fig. 2).

A calibration has been possible by comparing the results of the model with available level oscillation records and salinity measurements [3].

The following experimental data were used for calibration:

i) Salinity measurements during part of a tidal cycle, recorded on March 30, 1971, on sections 4, 6 and 7 (see Fig. 4).

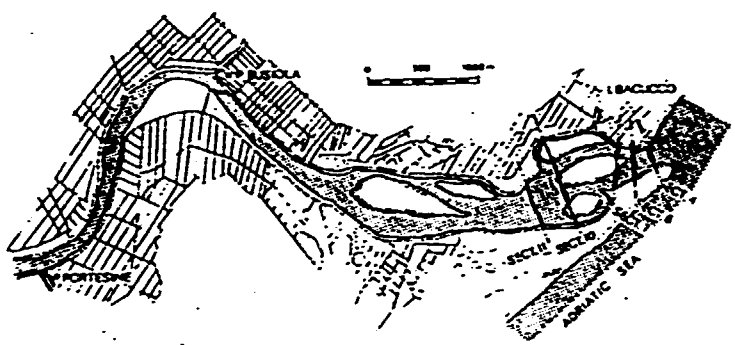


Fig. 4 - Terminal reach of the Adige River. Measurement sections

During the test, inland discharge was constant and equal to 185 m^3/s; the sea level oscillation was about ± 0.3 m with respect to the mean sea level, with a period of about 12 hours.

ii) Salinity measurements during part of a tidal cycle, recorded on December 21, 1971, on sections 6, 10, 11 (see Fig. 4).

During the test, inland discharge was constant and equal to 50 m^3/s (an exceptionally low discharge for the Adige River); the sea level oscillation was ± 0.2 with respect to the mean sea level, with a period of about 12 hours.

iii) Level oscillation records during several tidal cycles, recorded on November 2nd and 3rd, 1972 at three locations along the river (see Fig. 2): Isola Bacucco (at the river mouth); Porto Fossone (3.2 km upstream the mouth); Cavanella (11 km upstream the mouth). During the test, the inland discharge was practically constant and equal to 104 m^3/s.

Three parameters have been tested for calibration: interfacial friction coefficient f_s, river bed friction coefficient f, and densimetric ratio between salt

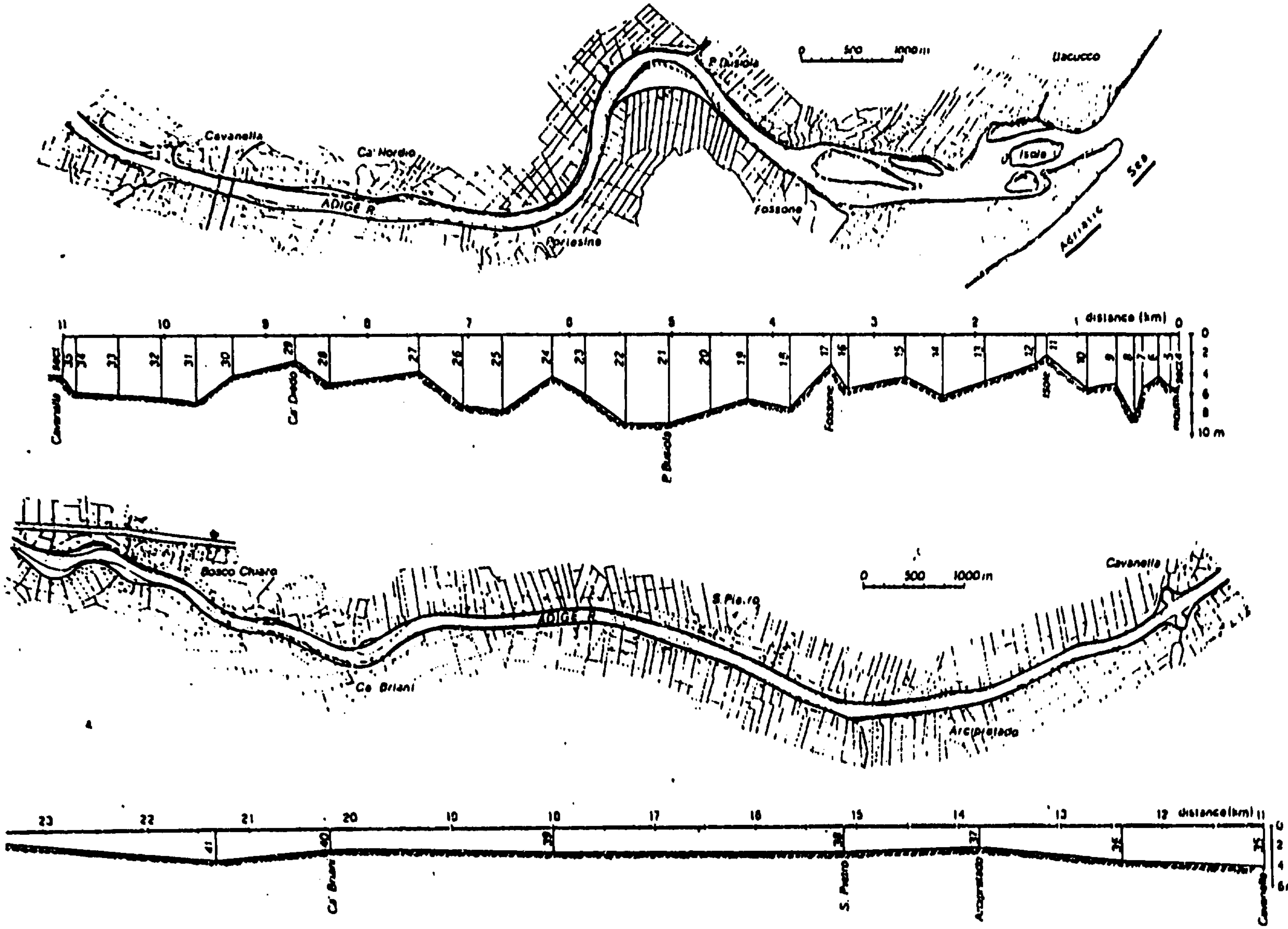


Fig. 2 - Morphological characteristics of the lower part of the Adige. The cross sections shown in the figure have been reproduced on the model.

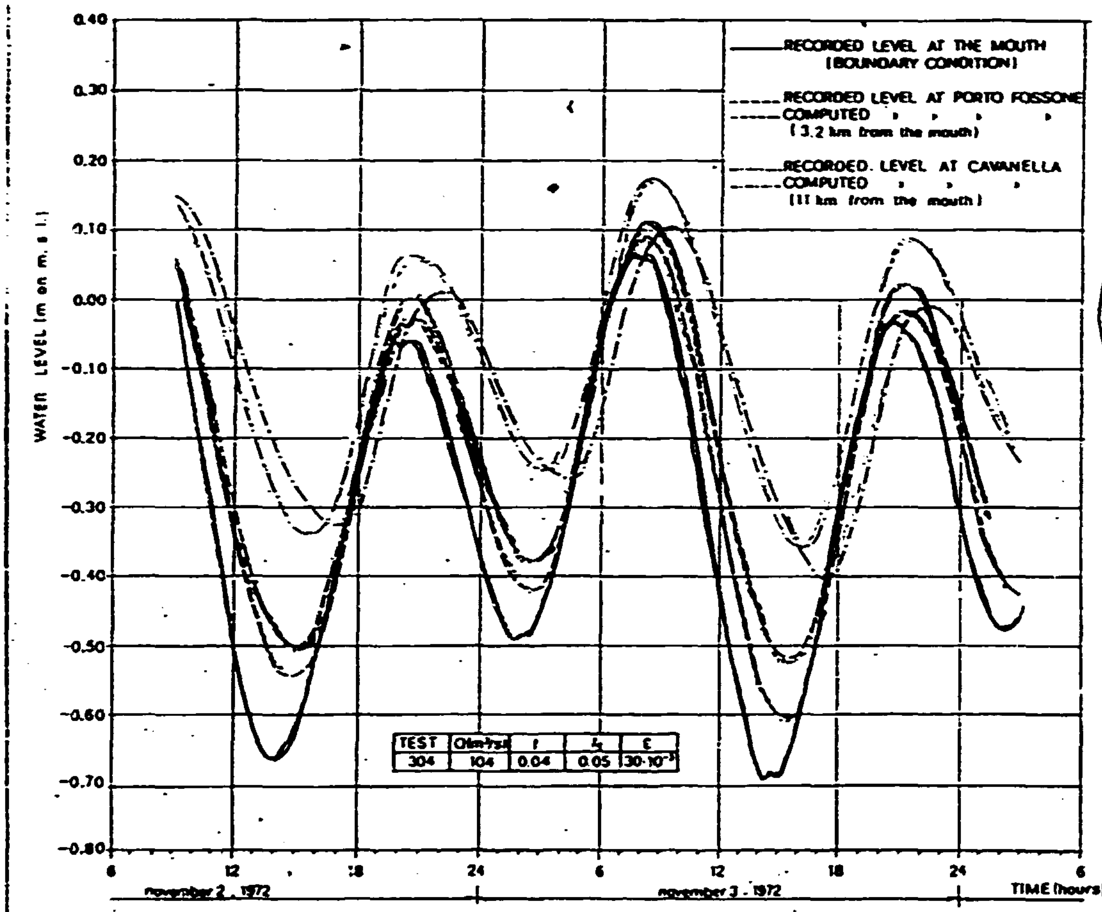
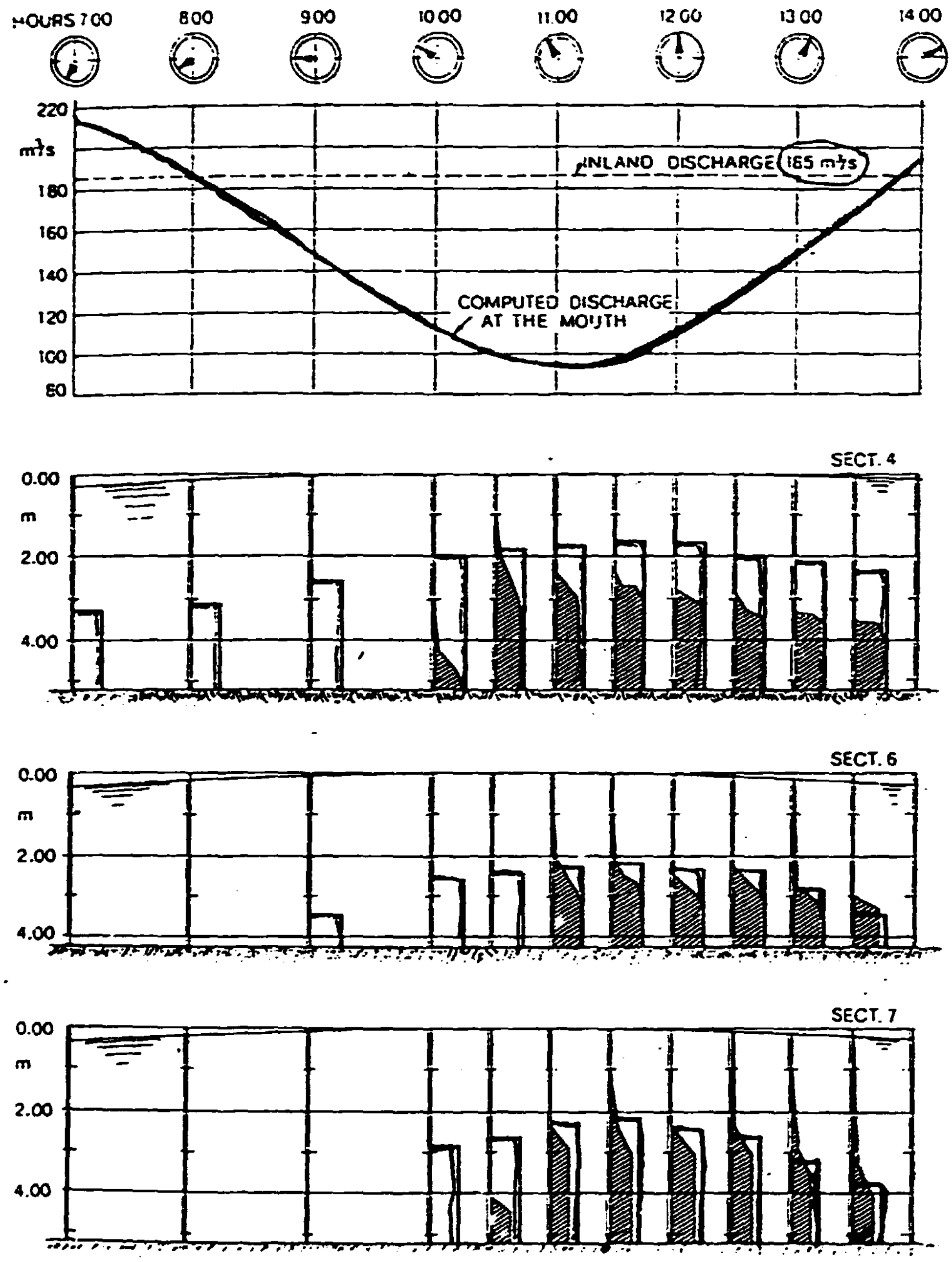


Fig. 5 – Damping of the tidal oscillation along the lower part of the Adige River from the mouth (Sect. 4) to Porto Fossone (Sect. 16) and to Cavanella (Sect. 35). Comparison between computation and level records of November 1972.



0 100 g/l
salt concentration

computed measured

TEST	Q (m³/s)	f	f_s	ε
111	185	0.04	0.05	$30 \cdot 10^{-4}$

Fig. 6 - Comparison between experiments and computations. Salinity measurements : March 1971.

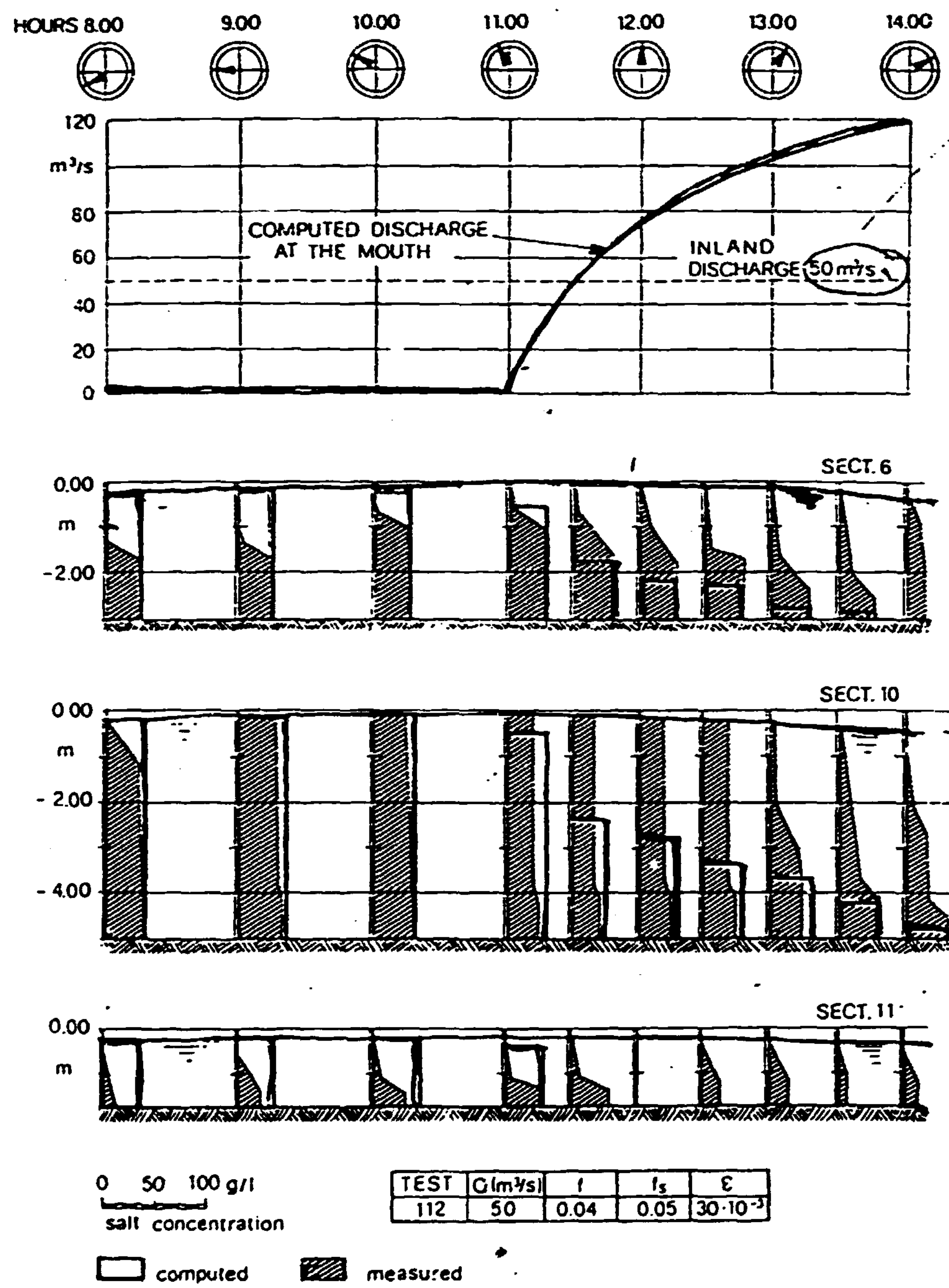
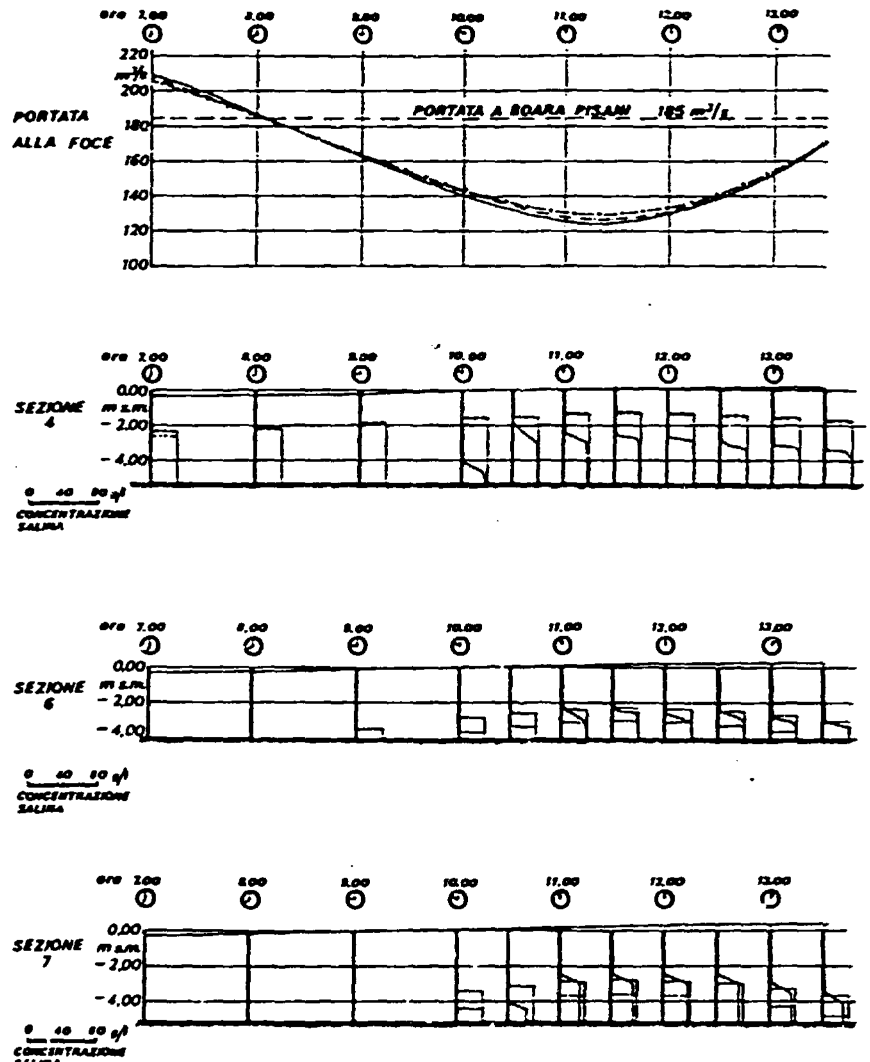
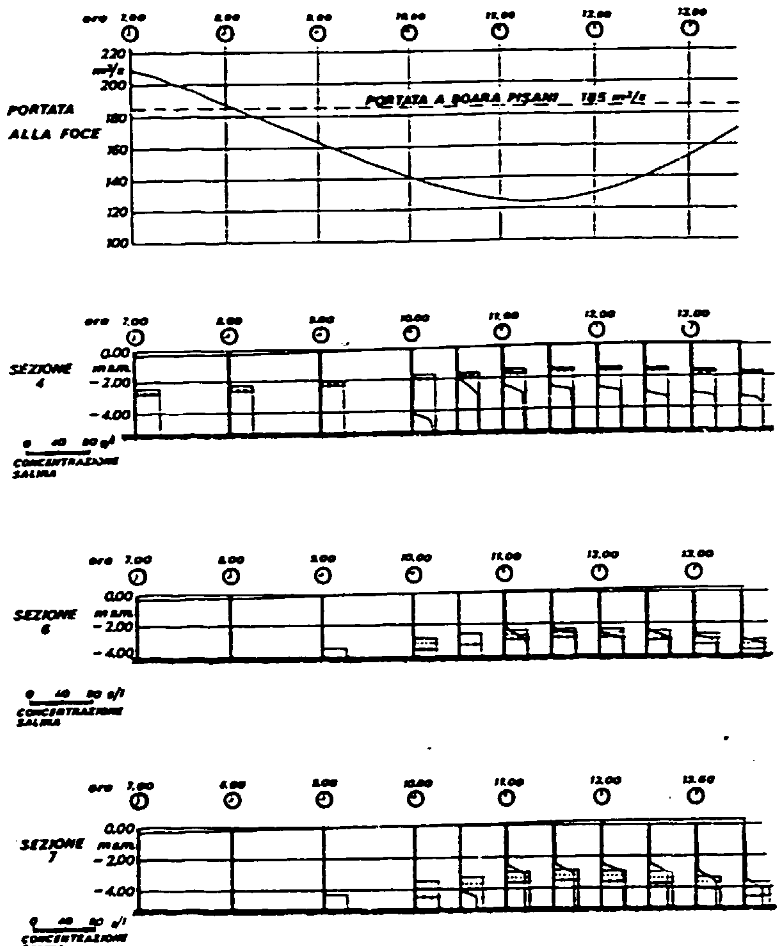


Fig. 7 - Comparison between experiments and computations. Salinity measurements : December 1971.



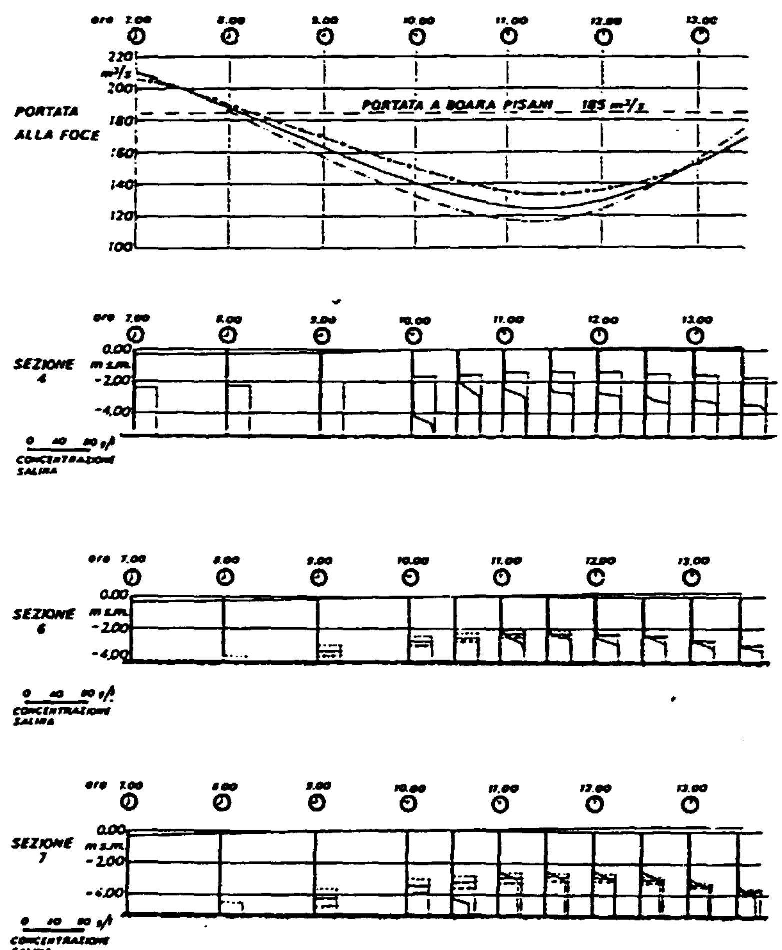
PROVA	f	f_s	c
—101—	0.10	0.05	$30\ 10^{-3}$
—110—	"	0.10	"
—103—	"	0.20	"

Fig.7 - Effetti del coefficiente di resistenza all'interfaccia f_s.



PROVA	f	f_0	ε
—101—	0.10	0.05	$30 \cdot 10^{-3}$
--116--	"	"	$25 \cdot 10^{-3}$
—115—	"	"	$20 \cdot 10^{-3}$

Fig.8 - Effetti del rapporto densimetrico $\varepsilon = \dfrac{\rho_A - \rho_B}{\rho_A}$.



PROVA	f	f_i	ε
- - 113 - -	0.05	0.05	$30 \cdot 10^{-3}$
—101—	0.10	..	..
—114—	0.15	..	..

Fig.9 - Effetti del coefficiente di resistenza dell'alveo f.

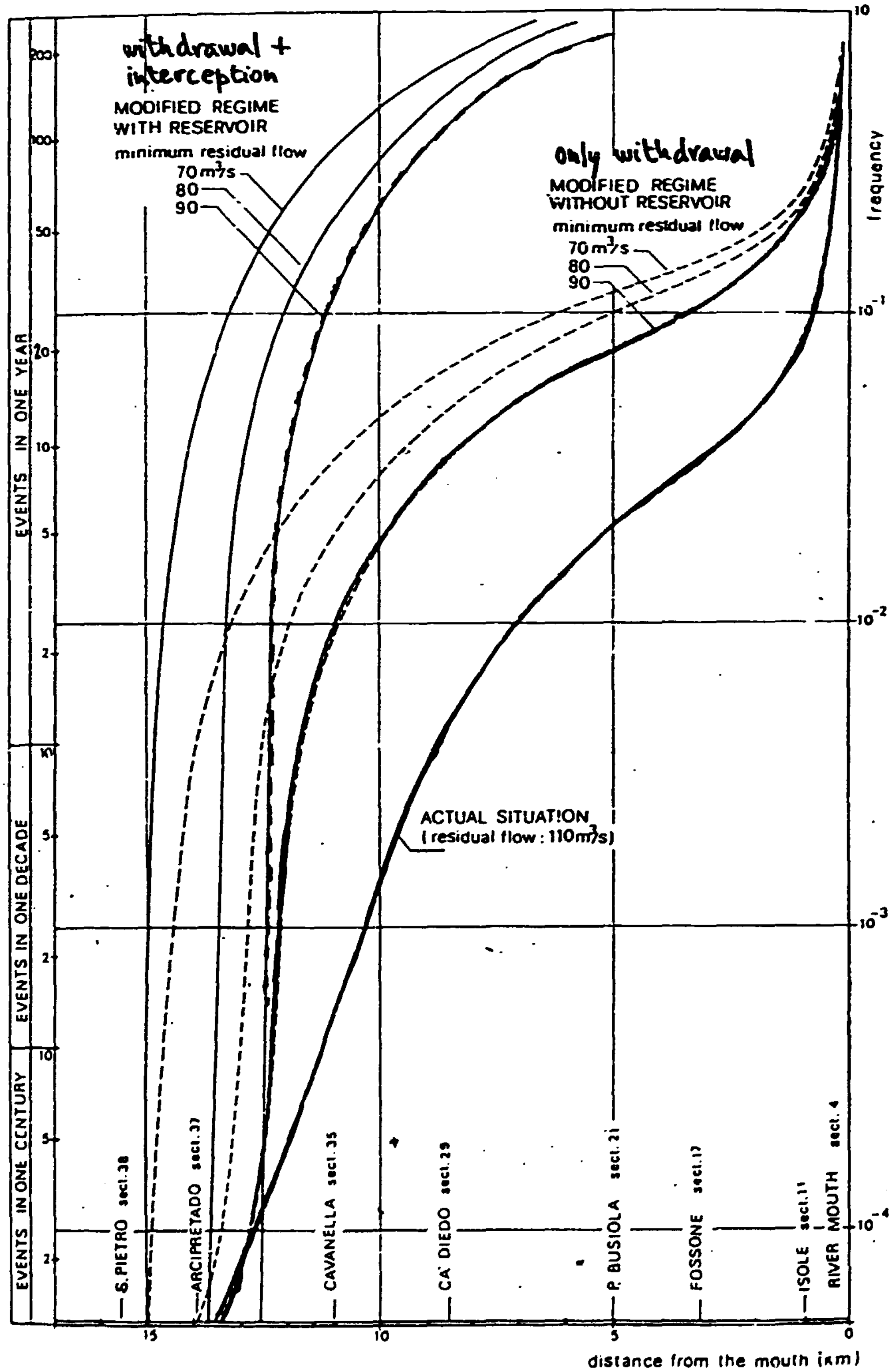
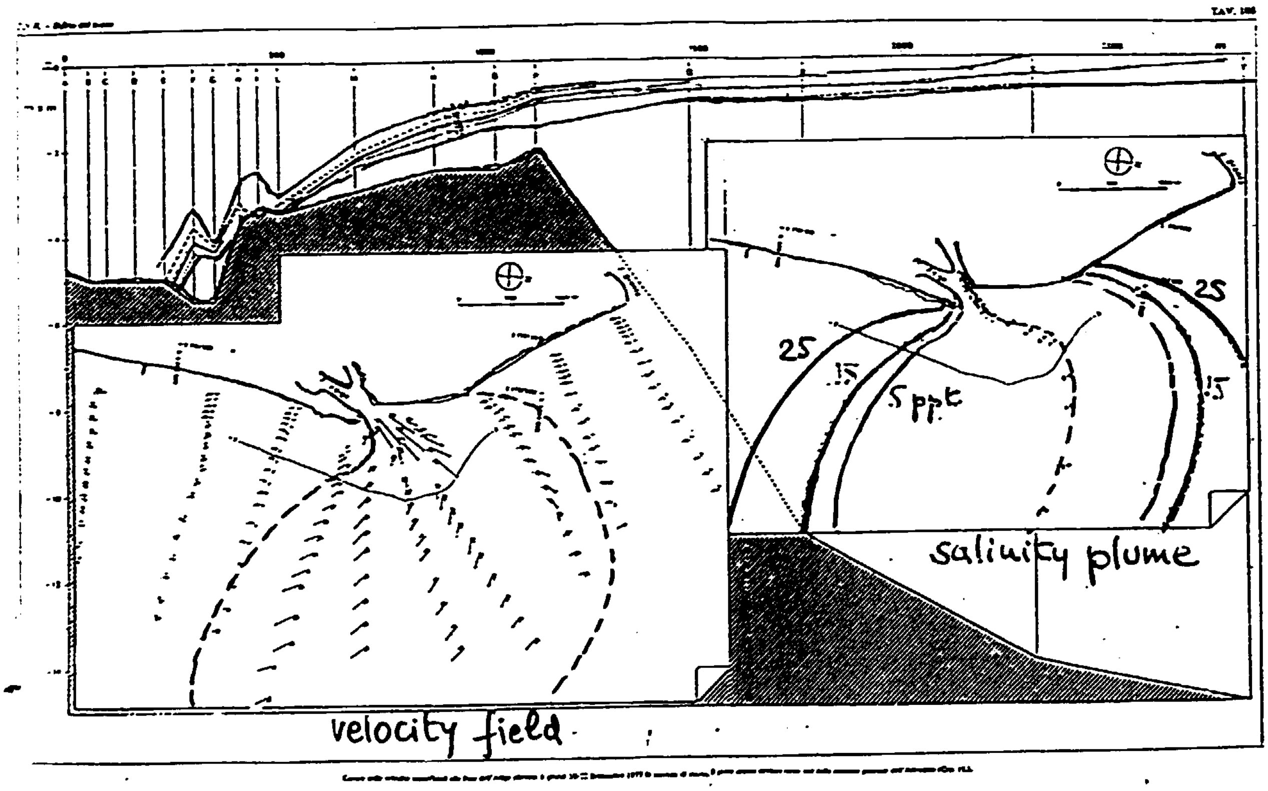


Fig. 8 - Adige River: Effects of possible modifications of the hydraulic régime on t. frequency of maximum salt wedge intrusion.

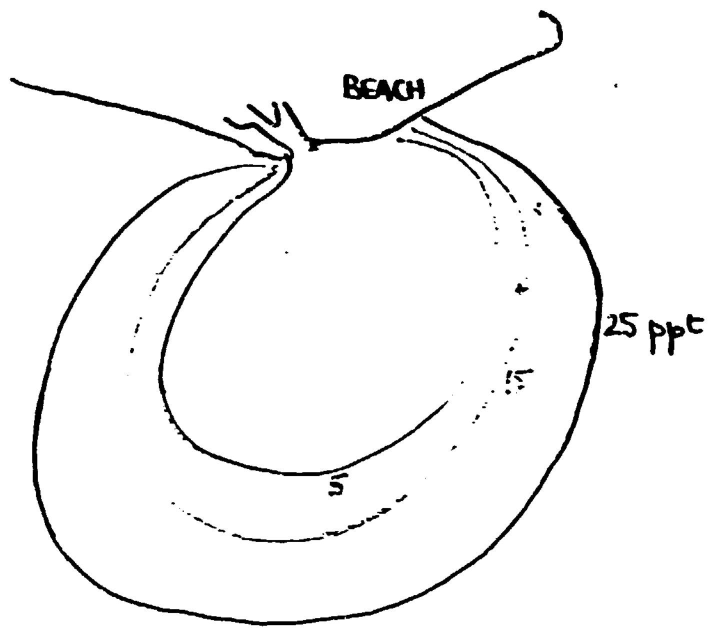
TIDAL DELTA OF THE ADIGE RIVER

EXTERNAL HYDRODYNAMICS

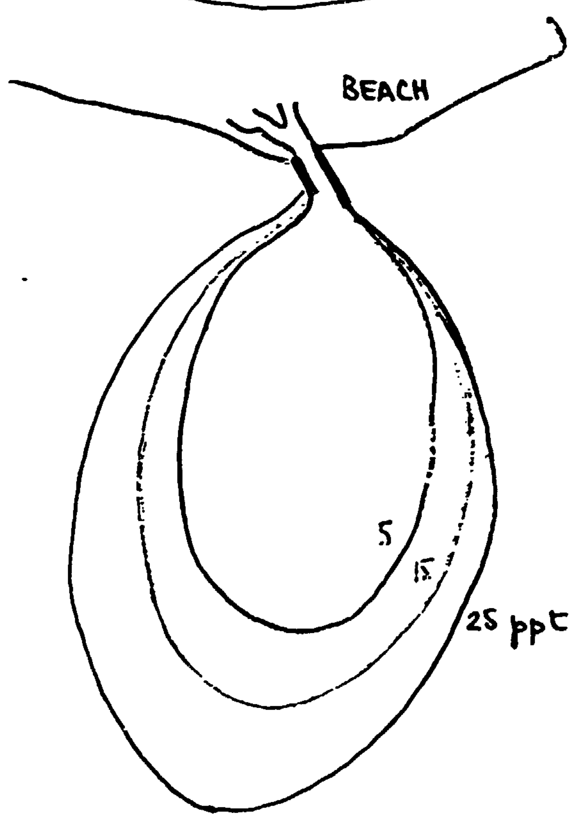


TIDAL DELTA OF THE ADIGE RIVER

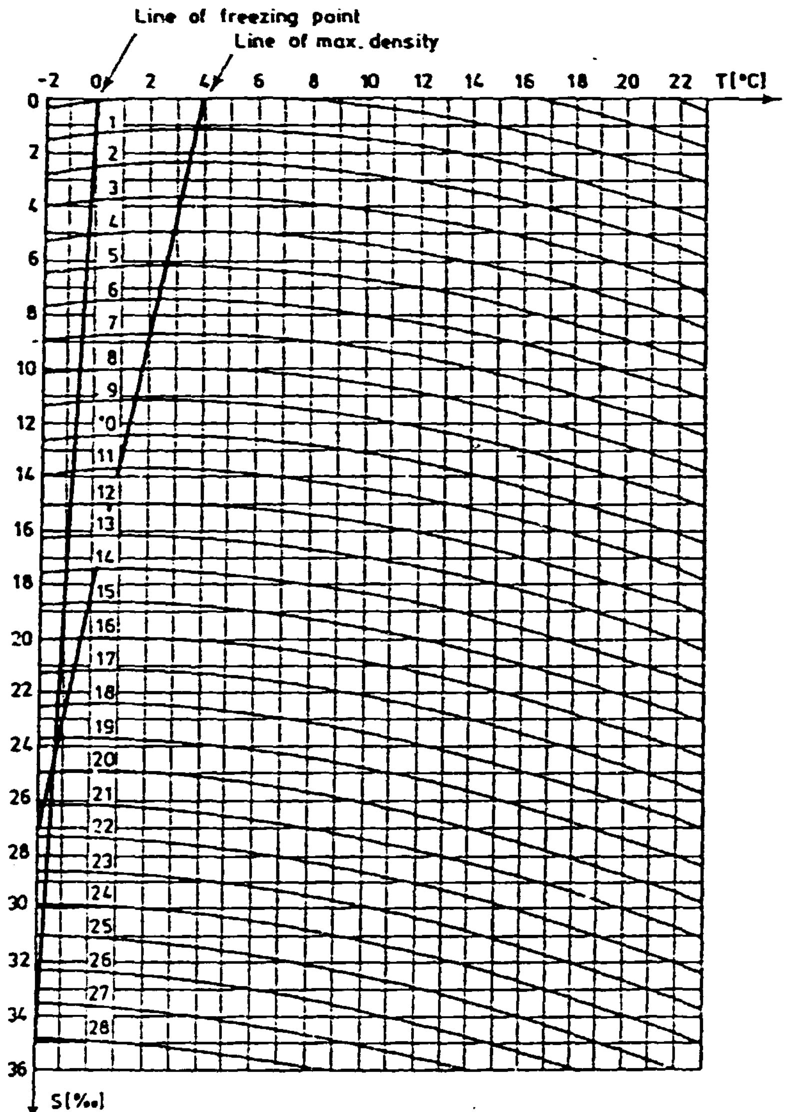
BEACH PROTECTION (SIDE EFFECTS !)



Present situation



With (temporary) jetties



RELATIVE DENSITY $\sigma = (\rho - 1000)/1000$ of sea-water for various temperatures and salinity

Giampietro Di Silvio

Università di Padova

UNESCO - International Hydrological Programme

A case of study: the Adige river

UNESCO - INTERNATIONAL HYDROLOGICAL PROGRAMME

Working group on changes in the salt-fresh water balance in deltas, estuaries and coastal zones due to structural works and groundwater exploitation.

A CASE STUDY: THE ADIGE RIVER

Prepared by Prof. G. Di Silvio
Institute of Hydraulics, University of Padua (Italy)

1. - Introduction

The Adige River is the second longest river (400 km) and has the third largest hydrographic basin in Italy (12,000 km^2). Most of the basin is contained in the alpine region, with elevations up to 3900 m above the sea level (Fig. 1).

The Adige River and its tributaires flow across rather populated and urbanized areas, both in the alpine and plain region: 1.2 millions of inhabitants presently live within the basin, and they are expected to become 1.6 millions before the year 2015.

A large amount of the Adige's water (800 . 10^6 m^3 per year) is already used for industrial, agricultural and municipal purposes, but an additional volume (500 . 10^6 m^3) should be derived from the river in order to meet the entire demand of the territory, above all the irrigation requirements of the large alluvial plain down-stream the city of Verona.

Although the water volumes to be derived from the river are relatively small in comparison with the average annual runoff (7400 . 10^6 m^3), the situation appears to be more serious as far as the discharges are concerned. During the irrigation period, in fact, the maximum diversion from the river is at present of 180 m^3/s. In this conditions, the residual discharge at the mouth of the river is still larger then 110 m^3/s (duration along the irrigation period: 95%). However, if an additional discharge is to be diverted from the river, the residual flow at the mouth is going to be substantially reduced, and an excessive intrusion of salt water from the sea could eventually take place.

A study on the possible utilization of the Adige River water resources has been done by a Government Agency (Ente Nazionale per le Tre Venezie) operating in North East Italy [1]. In this study, retention and storage of water by means of new reservoirs has been taken into consideration, together with a reduction of the minimum residual flow let to get into the sea.

In order to predict the effects of modifications of the hydrological régime on the balance between fresh and salt water in the lower part of the Adige River (Fig. 2), a mathematical model of the estuary was prepared simulating the salt intrusion hydrodynamics.

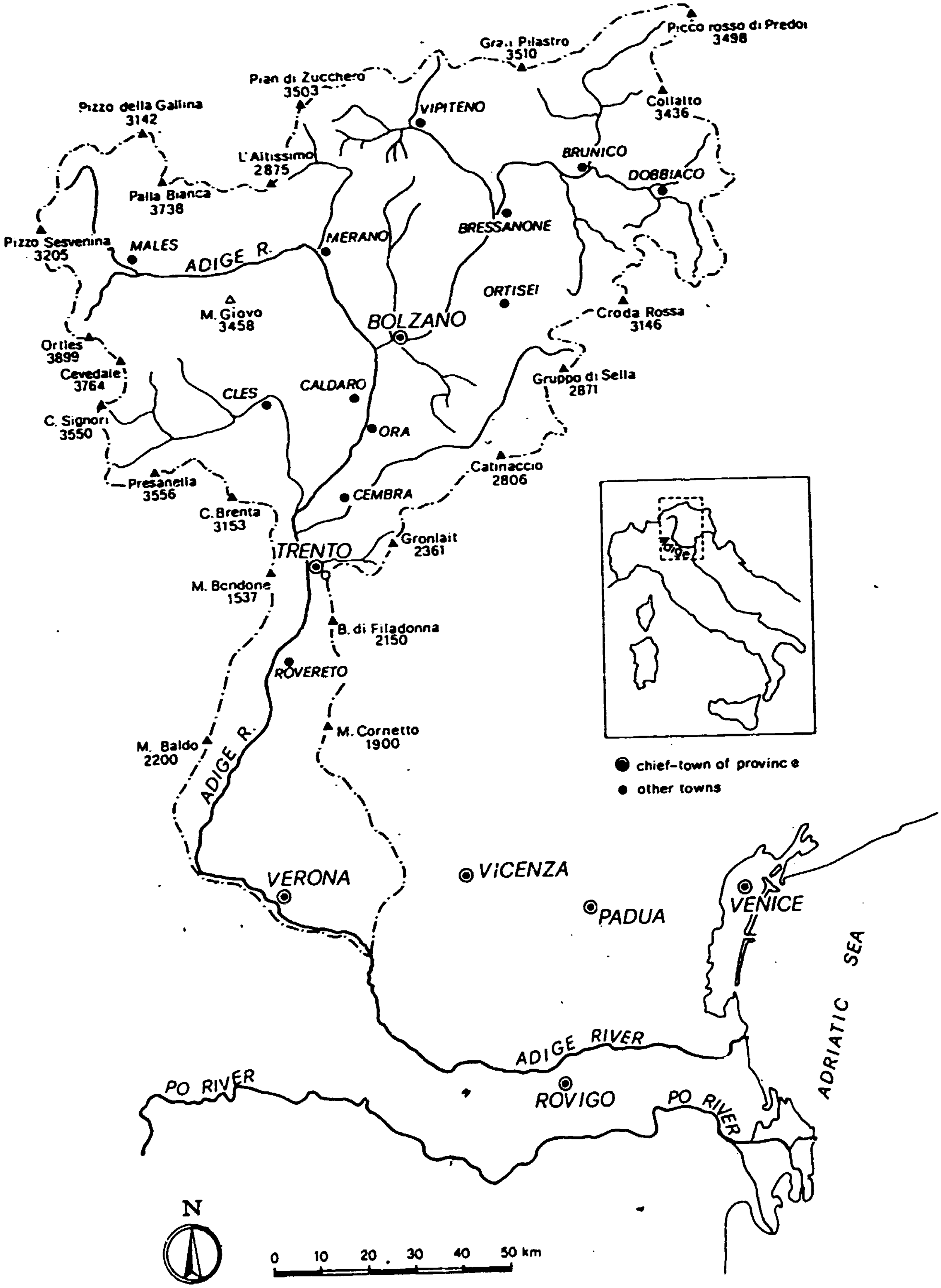


Fig. 1 - Hydrographic basin of the Adige River

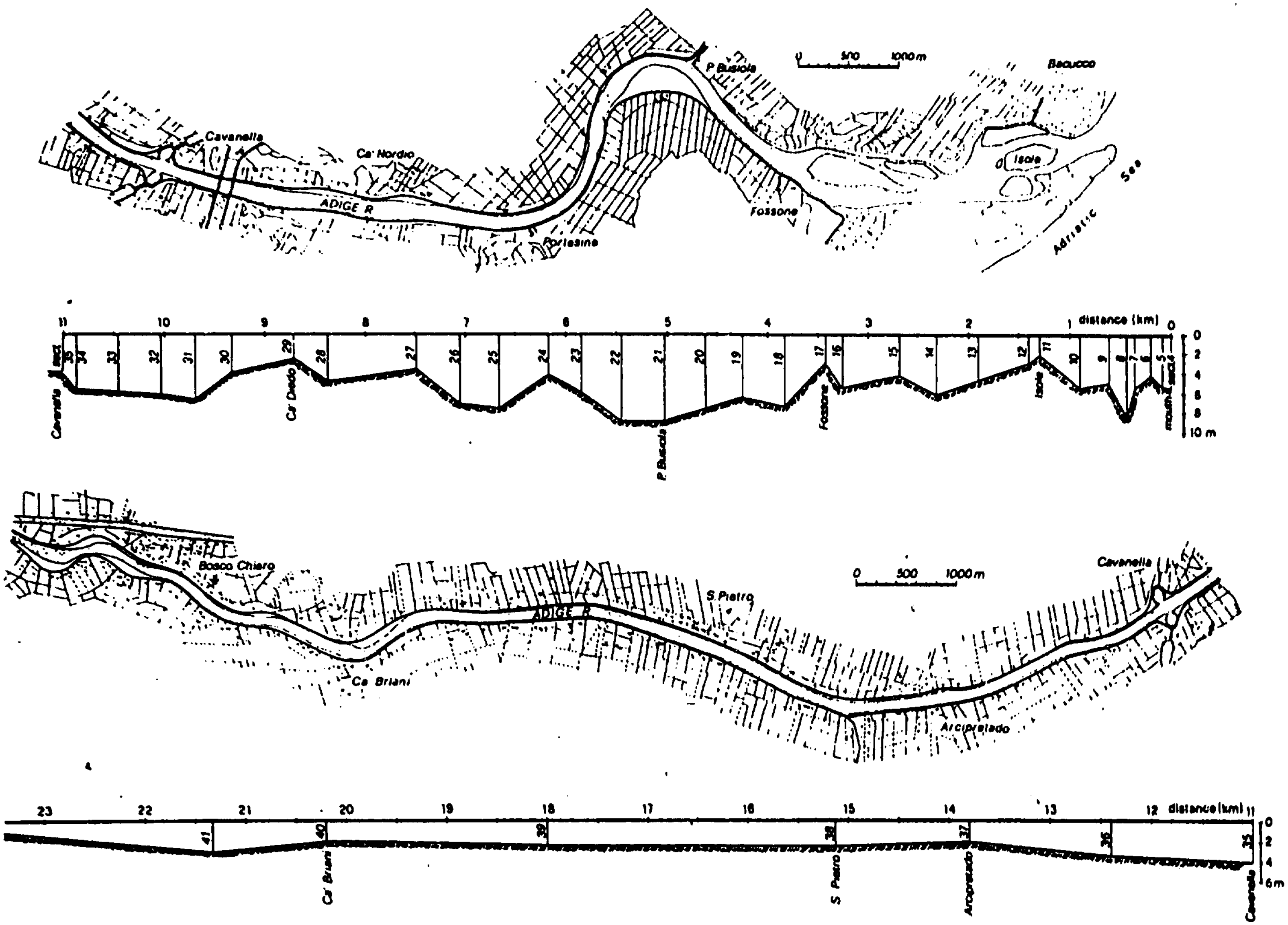


Fig. 2 - Morphological characteristics of the lower part of the Adige. The cross sections shown in the figure have been reproduced on the model.

2. - Salt intrusion mathematical model

Classification of salt water intrusion in estuaries, according to the degree of stratification, may be made following a number of criteria taking into account different morphological and hydraulic parameters. However, since the estuary morphology is related to the tidal action and to the fresh water discharge, most of these criteria may be brought back to the simple Pritchard criterion based on the ratio between the tidal prism volume and the volume of inland water flowing toward the sea during one tidal cycle.

Spring tide in northern Adriatic Sea is about 1 m from maximum to minimum. As a consequence, even with the largest planned reductions of residual inland discharge, the above mentioned ratio for the Adige River is nearly always less then 1, so that intrusion is markedly stratified (unsteady salt wedge).

A mathematical model has been prepared [2], consisting in the numerical integration of the four one-dimensional equations of motion and continuity in two layers having different density (fresh and salt water).

Energy losses in the two layers have been put into account, according to the Darcy-Weisbach formula, by a friction coefficient f on the river bed and by a friction coefficient f_s on the interface.

Since in stratified estuaries the velocity of the lower salt-water layer is usually small in comparison with the velocity of the upper fresh - water layer, the energy dissipation (for unit weight and unit length) within the two layers, i_A and i_B, has been assumed as depending only on the fresh water velocity:

$$i_A = - \frac{1}{8g} Q_A | Q_A | \frac{f(P_A - P_B) + f_s B_B}{(A_A - A_B)^3}$$

$$i_B = - \frac{1}{8g} Q_A | Q_A | \frac{f_s B_B}{A_B (A_A - A_B)^2}$$

where Q_A is the fresh water discharge; A_A and A_B the channel cross sections at elevations y_A (fresh water surface) and y_B (salt water surface); B_A and B_B the channel widths at elevations y_A and y_B; and P_A and P_B the wetted perimeters, again at elevations y_A and y_B.

Salt-water velocity could also be included in the dissipation formula, but a substantial improvement is hardly to be expected, due to the uncertainty in quantifying the coefficient f_s (see par. 3).

The four partial differential equations of motion and continuity have been solved by a finite-difference technique, leading to an implicit scheme for the upper layer (fresh water) and to an explicit scheme for the lower layer (salt water).

Appropriate boundary conditions are prescribed at the sea-end and at the inland-end of the river, in order to take into consideration all the possible configurations (Fig. 3).

In the inland-end (far enough from the mouth, so that tidal oscillations have no influence there) the time-depending inland discharge Q_A, entering the river, is prescribed.

In the sea-end the time-depending level y_A (varying according to the tide) is prescribed. When the intermediate situation takes place (Fig. 1 b), a further condition is given at the sea-end boundary, i.e. the minimum energy compatible with discharge Q_A and the sea level y_A. This condition leads to:

$$F_R = \frac{Q_A \quad \varepsilon B_A + (1 - \varepsilon)\, B_B}{\varepsilon g\, (A_A - A_B)^3} = 1$$

where F_R is the densimetric Froude number and $\varepsilon = \dfrac{\rho_B - \rho_A}{\rho_B}$ is the densimetric ratio.

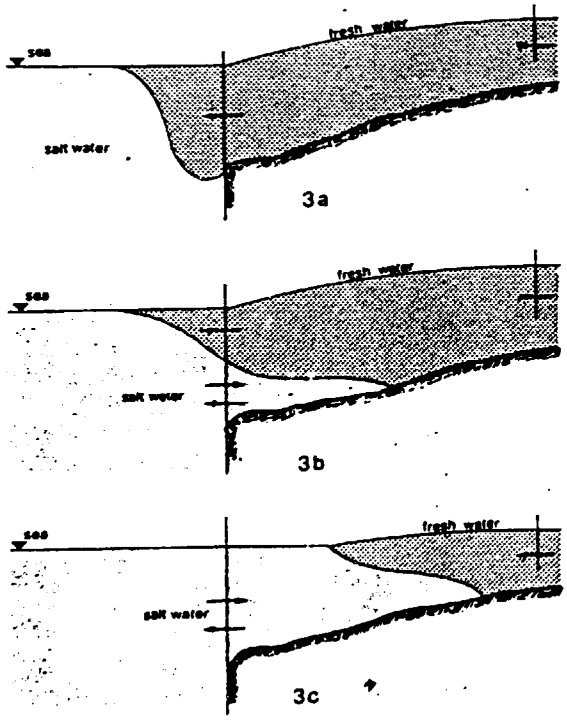


Fig. 3 a - Driven back intrusion (strong ebb-tide and high inland discharge)
Fig. 3 b - Deep salt intrusion (intermediate situation)
Fig. 3 c - Superficial salt intrusion (strong flood-tide and low inland discharge)

3. - Calibration of the mathematical model

The lowest part of the Adige River has a rather irregular morphology: its mean depth ranges between 2 and 4 m, and its width between 100 and 300 m. About 40 cross sections (more and more closely distributed toward the mouth) have been used for an accurate geometrical description of a 26 km long reach of the river (Fig. 2).

A calibration has been possible by comparing the results of the model with avai lable level oscillation records and salinity measurements [3] .

The following experimental data were used for calibration:

i) Salinity measurements during part of a tidal cycle, recorded on March 30, 1971 , on sections 4, 6 and 7 (see Fig. 4).

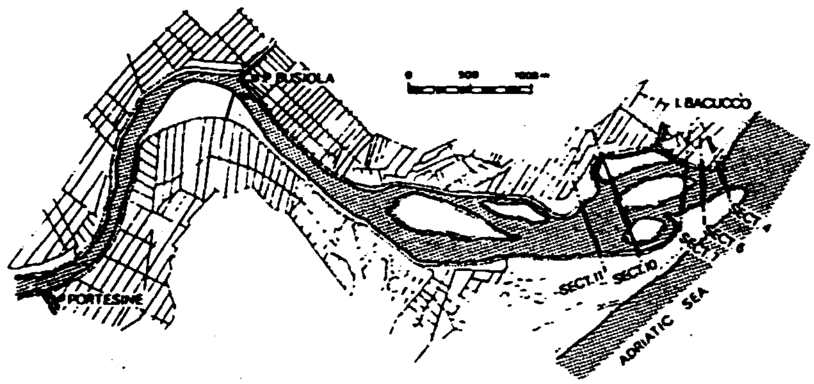


Fig. 4 - Terminal reach of the Adige River. Measurement sections

During the test, inland discharge was constant and equal to 185 m^3/s; the sea level oscillation was about $\pm$ 0.3 m with respect to the mean sea level, with a period of about 12 hours.

ii) Salinity measurements during part of a tidal cycle, recorded on December 21 , 1971, on sections 6, 10, 11 (see Fig. 4).

During the test, inland discharge was constant and equal to 50 m^3/s (an exceptionally low discharge for the Adige River); the sea level oscillation was $\pm$ 0.2 with respect to the mean sea level, with a period of about 12 hours.

iii) Level oscillation records during several tidal cycles, recorded on November 2nd and 3rd, 1972 at three locations along the river (see Fig. 2): Isola Bacuc co (at the river mouth); Porto Fossone (3.2 km upstream the mouth); Cavanella (11 km upstream the mouth). During the test, the inland discharge was practically constant and equal to 104 m^3/s.

Three parameters have been tested for calibration: interfacial friction coefficient f_s , river bed friction coefficient f, and densimetric ratio between salt and fresh water, $\varepsilon = \frac{\rho_B - \rho_A}{\rho_B}$.

Specification of the numerical values for these parameters is not an easy task, expecially as far as the interfacial friction is concerned. Values of f_s obtained from several experiments in steady conditions, both in laboratory and in nature, are scattered within a couple of orders of magnitude [3] .

Although the coefficient f_s is expected to be somehow depending on the flow characteristics, it has been decided to assume it as a constant during each calibration test. In this way, the friction coefficient f_s is reckoned as an overall calibration parameter allowing a satisfactory fitting of the experimental results. The same has been done as far as the river bed coefficient f and the densimetric ratio ε are concerned.

An extensive combination of these coefficients has been tested on the model. The values of f and f_s ranged from 0.01 up to 0.20; the values of ε ranged from 0.20 up to 0.30.

The sensitivity analysis shows that a precise specification of the densimetric ratio is not much relevant, provided that a reasonable value corresponding to the salt concentration in the sea is used. Much more important, as expected, is the influence of the friction coefficient, both on the interface and on the river bed.

The interfacial friction coefficient directly affects the salt-wedge profile in that the friction forces tend to push the intrusion back to the sea. They are especially important when the inland discharge is large in comparison with the tidal oscillation.

The river bed friction coefficient is important in so far as it influences the periodic variation of the fresh-water discharge at the mouth (the smaller the bed friction is , the larger is the tidal prism volume). This is especially important for salt intrusion when the inland discharge is relatively small, since the discharge at the mouth may be strongly reduced during the flood period (or even annuled as shown in Fig. 3 c).

After different trials, the following constant (in space and time) values have been recognized to duplicate all the available data with sufficient accuracy; reasonable variations of these values, however, do not markedly affect the salt intrusion.

River-bed resistance coefficient: $f = 0.04$ (corresponding to a value of 45 $m^{1/2}$ s^{-1} in the Chézy formula)

Interfacial resistance coefficient: $f = 0.05$ (corresponding to a value of 40 $m^{1/2}$ s^{-1} in the Chézy formula)

Densimetric ratio: $\varepsilon = 0.03$ (corresponding to the average salinity of the Adriatic Sea).

The tidal wave attenuation along the river is shown in Fig. 5, where a comparison is given between computation and level records of November 1972.

In Figs. 6 and 7 a comparison is given between salt wedge configurations provided by experiments and computations. During salinity measurements of March 1971 (Fig. 6), the maximum reduction of the inland discharge at the mouth was less than 50%; in such a case the salt wedge intrusion is mainly controlled by interfacial friction f_s. Duplication is fair, but the advancing of the salt wedge during the flood period seems to be more sudden in nature than in the mathematical model.

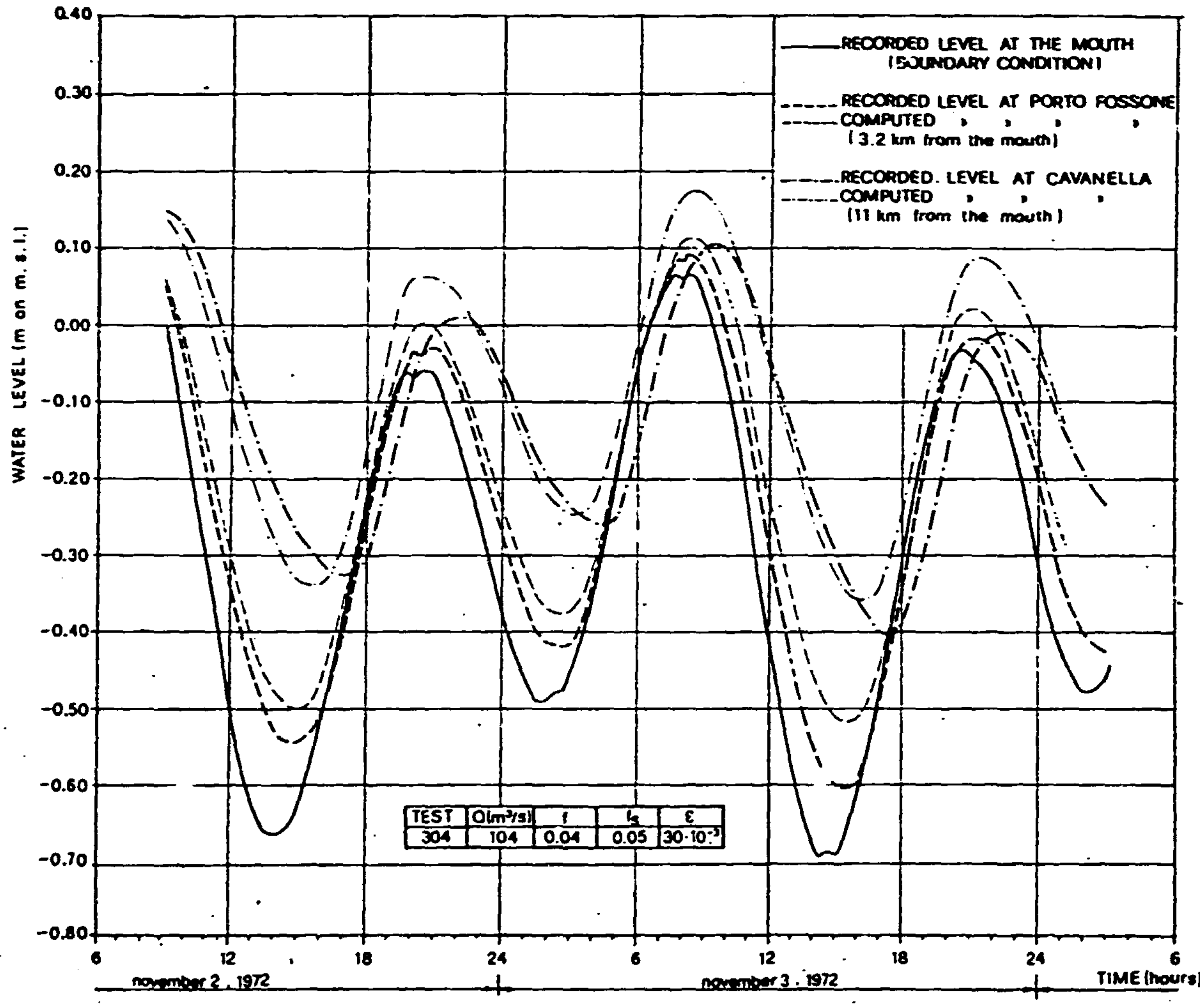
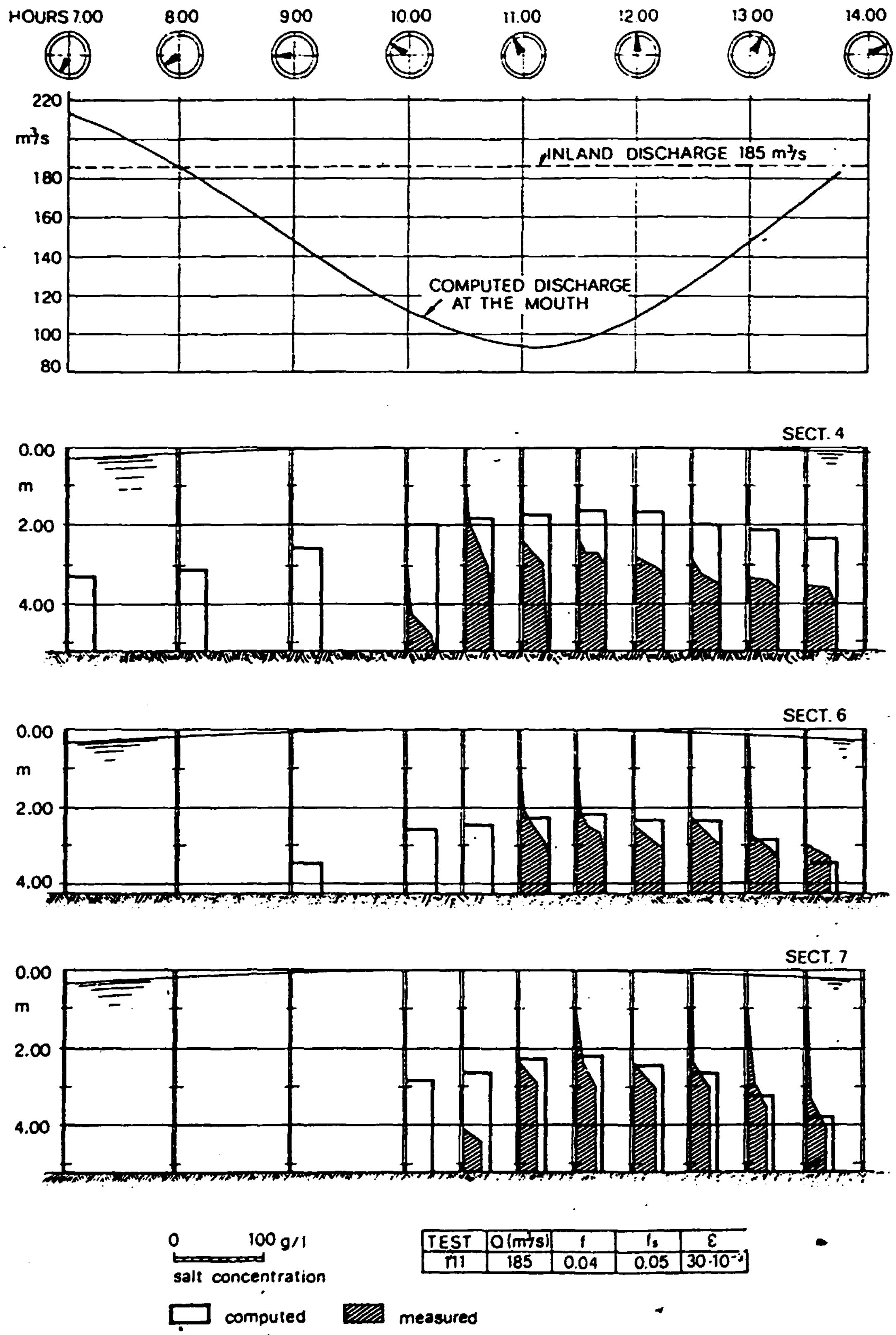
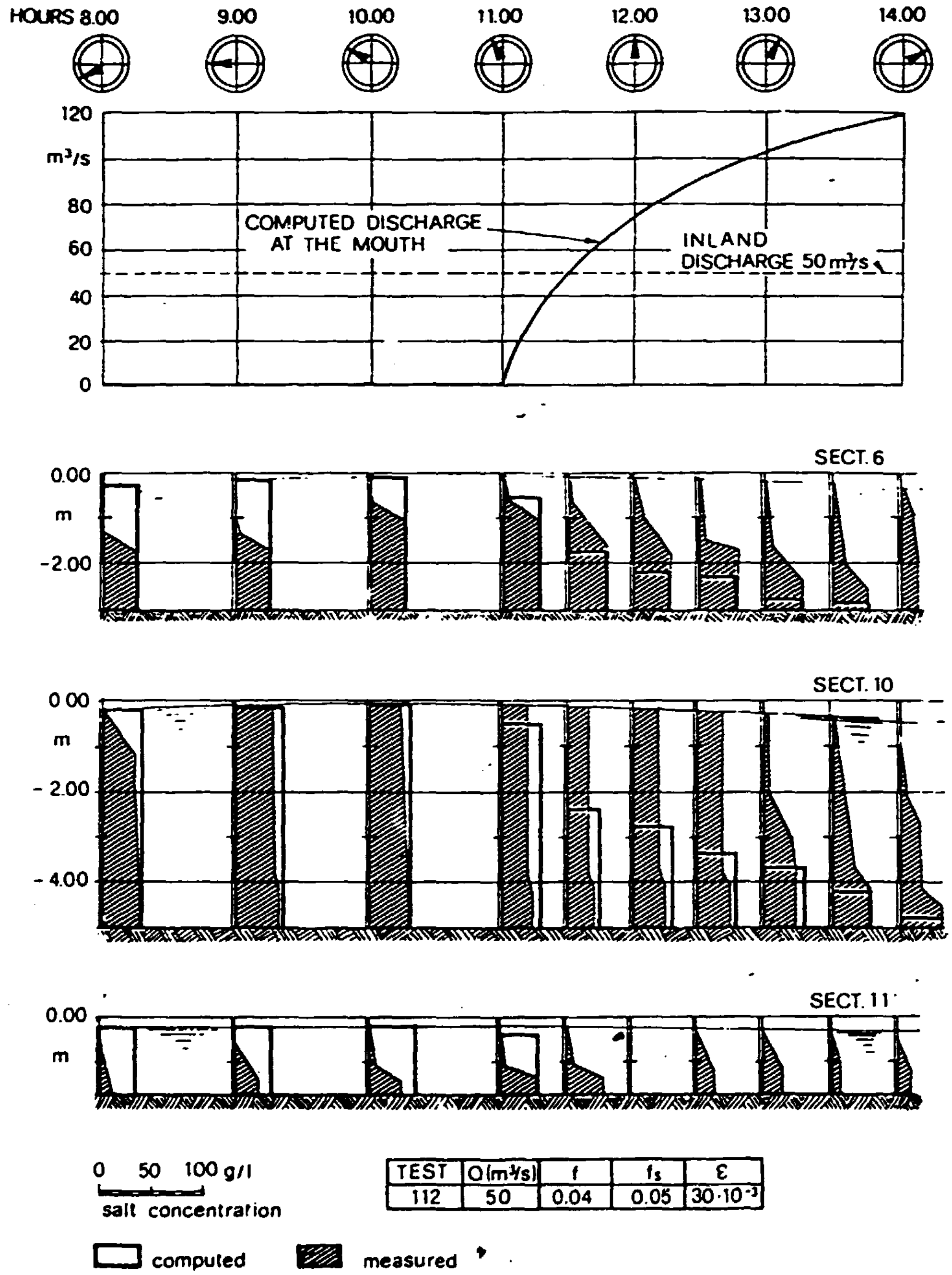


Fig. 5 – Damping of the tidal oscillation along the lower part of the Adige River from the mouth (Sect. 4) to Porto Fossone (Sect. 16) and to Cavanella (Sect. 35). Comparison between computation and level records of November 1972.



TEST	Q (m³/s)	f	f_s	ε
T11	185	0.04	0.05	$30 \cdot 10^{-3}$

Fig. 6 - Comparison between experiments and computations. Salinity measurements : March 1971.



TEST	Q (m³/s)	f	f_s	ε
112	50	0.04	0.05	$30 \cdot 10^{-3}$

Fig. 7 - Comparison between experiments and computations. Salinity measurements : December 1971.

During salinity measurements of December 1971 (Fig. 7), the inland discharge was so low that a superficial intrusion of salt water during the flood period took place like in Fig. 3 c. As a matter of fact, a salt concentration of almost 30 g/l has been measured on the surface of Sect. 10, even if, surprisingly, no salt water has been detected at the surface of Sect. 6, much more downstream. This strange occurrence may perhaps be explained by the presence of a fresh-water pocket trapped along the side of the river in proximity of Sect. 6.

Although the mathematical model is not obviously able to reproduce this peculiar feature of the phenomenon, the simulation is rather good in Sect. 10 and 11. Even in Sect. 6, on the other hand, the salt wedge regression begins (according to the measurements) at about 11 o'clock, that is when the (computed) fresh water discharge starts to flow again thourgh the mouth.

More or less acceptable results, on the whole, can also be obtained with values of f and f_s ranging from 0.03 up to 0.10: the corresponding variations of the interface level are contained within 1 m, that is within the thickness of the experimental mixing layer. As far as the maximum lenght of intrusion is concerned, the most important parameter is definitely the bottom profile; for a certain condition of tide and inland discharge, in fact, the salt wedge displacement tends to be arrested by the same shoal along the river bed, even if the parameters f and f_s are modified.

3. - Results of the investigation

In order to evaluate the consequences of future possible modifications of the Adige River régime, a systematic investigation has been carried out on the mathematical model, calculating the salt wedge movement for a large number of different combinations of semidiurnal (sinusoidal) tides and inland discharge.

Subsequently, a statistical analysis of tidal ranges in the Adriatic sea and river discharges has been made, either in the actual situation or with different hypothesis of further derivation of water (both with and without the effect of new reservoirs).

Besides the actual situation (minimum residual flow in the river of 110 m^3/s.) six possible modifications of the Adige river régime have been considered:

Modified régime without reservoirs: Increased derivations from the river during the irrigation period, with the constraint of allowing a minimum residual flow of 70, 80 and 90 m^3/s respectively.

Modified régime with reservoirs: Retention and utilization of all the discharges exceeding the minimum residual flow of 70, 80 and 90 m^3/s respectively.

As the salt intrusion is markedly stratified, the most significant feature to be evaluated is the maximum displacement of the wedge along the river. Then the maximum displacement corresponding to any combination of tide and discharge has been marked by the joint probability of these two (indipendent) events, and for each situation of the Adige River régime, the probability of maximum intrusion lenght has been plotted versus the distance from the mouth (Fig. 8).

The curves indicate either the more frequent presence of the salt in a certain place, or the lengthening of the salt intrusion for a certain probability of occurance, if the present conditions are modified.

By a comparison of the curves, the following observations may be made.

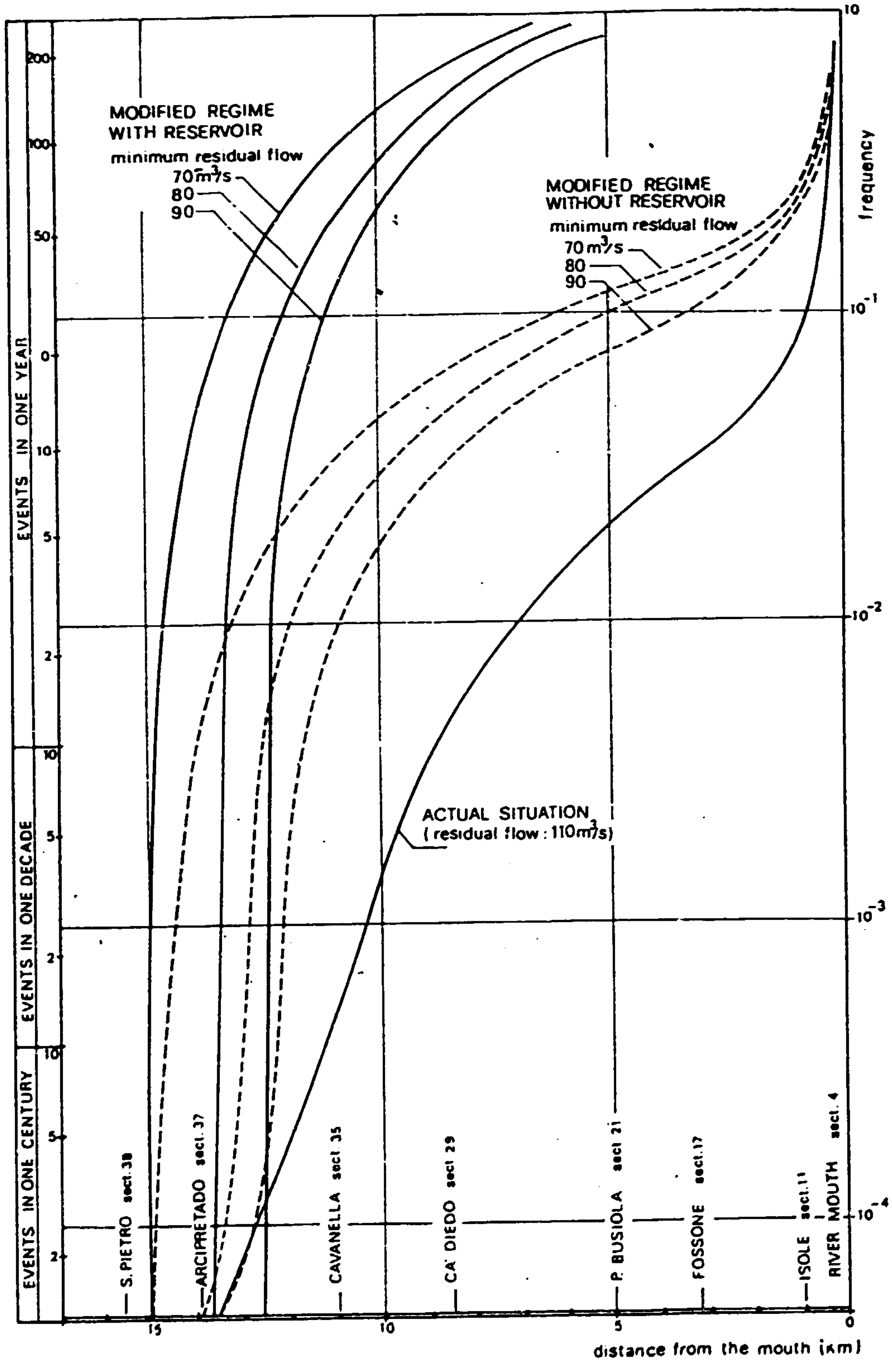


Fig. 8 - Adige River: Effects of possible modifications of the hydraulic régime on the frequency of maximum salt wedge intrusion.

Actual situation: with the present distribution of river discharges, the maximum intrusion is normally contained within 1 km from the mouth (90% of the events); occasionally (once in ten years) the salt wedge may reach Section 35 (village of Cavanella).

Modified situation (without reservoirs): With increased derivations, the maximum intrusion is normally (90% of the events) contained within 3-6 km from the mouth, depending on the residual discharge allowed to flow into the sea (70, 80 or 90 m^3/s). Section 35 (village of Cavanella) is reached much more frequently than in the actual situation.

Modified situation (with reservoirs): If a complete regulation of the present runoff is assumed (with the exception of a constant residual discharge of 70, 80 or 90 m^3/s), the salt-intrusion frequency only depends on the frequency of the tides. In this case the salt intrusion is largely increased, and the wedge normally reaches Section 35 (village of Cavanella).

The future policy of water utilization should be decided also on the basis of the curves plotted in Fig. 8. In fact, a substantial lengthening of the salt intrusion along the river (as well as an unaccettable more frequent presence of the salt wedge at a given location), implies removing all the actual derivation structures affected by these modifications.

It is to be noted that all the curves fall to negligible frequencies somewhere in between Cavanella (Section 35) and S. Pietro (Section 38). As a matter of fact, upstream this last section, the river is much more shallow than in the lower reach, so that the salt wedge advancement is definetely arrested here even with exceptional tides and very low discharges.

A last remark should be made about the mutual interference of river morphology and salt-wedge hydrodynamics.

The salt-wedge movement, as already observed, is very sensitive to any prominence of the river bottom: as one can see from Fig. 8, the frequency of the maximum intrusion tends to accumulate in correspondance with the shoals (for example, at Sections 11 and 17, by the two groups of islands). On the other hand, these same shoals are very likely produced by the local silting occurring where the wedge happens to be frequently arrested.

As a consequence, a possible migration of the shoals may take place, if the inland discharge régime is modified.

4. - References

[1] Ente Nazionale per le Tre Venezie - Gruppo di lavoro per la migliore utilizzazione a scopo irriguo delle disponibilità idriche del fiume Adige. Relazione conclusiva. Venezia, 1974.

[2] Di Silvio, G. e Linthout, E. - Modello matematico per lo studio dell'intrusione salina stratificata alle foci fluviali soggette a marea. - XIII Convegno di Idraulica e Costruzioni Idrauliche, Milano, 21-23 settembre 1972.

[3] Di Silvio, G. - Calibration of a Mathematical Model for the Stratified Salt Intrusion in Tidal River Mouths, Paper C33, Proc. of the XVI Congress of the International Association for Hydraulic Research, Sao Paulo, 27 July - 1 August, 1975.

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MODELLO MATEMATICO PER LO STUDIO DELL' INTRUSIONE SALINA STRATIFICATA ALLE FOCI FLUVIALI SOGGETTE A MAREA

MODELLO MATEMATICO PER LO STUDIO DELL'INTRUSIONE SALINA STRATIFICATA ALLE FOCI FLUVIALI SOGGETTE A MAREA.

Dott. Ing. Giampaolo DI SILVIO - Istituto di Idraulica, Padova
Erwin LINTHOUT - C.E.T. - Centro di Calcolo - Technital S.p.A., Verona

1. PREMESSE

L'aspetto con cui si presentano le correnti d'acqua dolce e salata nel tratto terminale di un corso d'acqua sfociante in mare può andare da quello di una dispersione completa delle due correnti, tale da dar luogo ad una concentrazione salina uniforme in ciascuna sezione del fiume e gradualmente decrescente da valle verso monte, fino a quello di due correnti omogenee stratificate, l'inferiore delle quali (cuneo salato) s'insinua al di sotto dell'acqua dolce anche per decine di chilometri di distanza dal mare.

Un'assai marcata dispersione delle due correnti si determina tutte le volte che le escursioni di marea mettono in gioco volumi di flusso e riflusso notevoli rispetto a quelli d'acqua dolce convogliati da monte, com'è il caso degli ampi estuari atlantici. S'incontra, al contrario, una stratificazione molto netta delle due correnti quando il volume d'acqua dolce che si scarica durante la fase di flusso è relativamente importante rispetto al volume di marea, il che, ad esempio, generalmente accade alle foci sottili del Mediterraneo, del Mar del Giappone, del delta del Missisipl.

In realtà, l'intrusione dell'acqua di mare alle foci fluviali presenta sempre un aspetto intermedio fra i due casi estremi esaminati, nel senso che, da un canto la salinità non è mai uniformemente dispersa nella sezione ma presenta comunque un carattere più o meno stratificato, con concentrazione crescente dall'alto verso il basso, dall'altro in nessun caso esiste una vera e propria superficie di separazione fra l'acqua dolce più leggera e quella salata posta sotto. E' tuttavia necessario mantenere questa schematizzazione poichè il fenomeno può venire indagato numericamente solo ricorrendo all'una o all'altra ipotesi semplificatrice.

Sull'intrusione salina dispersa Tatcher e Harleman hanno recentemente pubblicato un lavoro [1] nel quale si fa il punto sullo stato delle conoscenze in materia. In esso viene proposto un modello matematico a moto vario che tiene anche conto, in maniera semiempirica, del grado di stratificazione della corrente: numerose applicazioni ad estuari americani ed europei danno confronti molto soddisfacenti con i rilievi sperimentali.

Non molto numerosi nella letteratura sono i modelli matematici che descrivono l'intrusione salina sotto forma stratificata, in condizioni di moto vario. Fra questi ricordiamo quello allestito da Boulot e Daubert (e da essi applicato alle foci del Rodano), consistente nella integrazione numerica delle equazioni del moto per le due correnti sovrapposte [2].

Nel presente lavoro si propone un modello per certi versi analogo a quello di Boulot e Daubert, ma che differisce da questo sia nel procedimento d'integrazione numerica (implicito invece che esplicito), sia in certi particolari accorgimenti adottati per introdurre le condizioni al contorno. Il modello matematico proposto è stato applicato alla foce del fiume Adige, ponendo a confronto i risultati del calcolo coi rispettivi rilievi sperimentali. Ciò ha permesso di discutere il significato di alcuni coefficienti sperimentali che compaiono nelle equazioni, mettendo in evidenza la necessità - comune, del resto, ai modelli fisici - di un'accurata taratura.

2. IL SISTEMA DI EQUAZIONI

Le equazioni che governano il moto vario di due correnti sovrapposte di differente densità (acqua dolce e acqua salata), sono le seguenti:

$$\frac{\partial}{\partial x}\left(y_A + \frac{v_A^2}{2g}\right) = i_A - \frac{1}{g}\frac{\partial v_A}{\partial t} \qquad (1)$$

$$\frac{\partial Q_A}{\partial x} + B_A\frac{\partial y_A}{\partial t} - B_B\frac{\partial y_B}{\partial t} = 0 \qquad (2)$$

$$\frac{\partial}{\partial x}\left[y_B + \frac{\gamma_A}{\gamma_B}(y_A - y_B) + \frac{v_B^2}{2g}\right] = i_B - \frac{1}{g}\frac{\partial v_B}{\partial t} \qquad (3)$$

$$\frac{\partial Q_B}{\partial x} + B_B\frac{\partial y_B}{\partial t} = 0 \qquad (4)$$

in cui i simboli (cfr. Fig.1) hanno il seguente significato:

- x distanza lungo il corso d'acqua, misurata da valle verso monte;
- t tempo;
- y_A livello del pelo libero in superficie, rispetto al l.m.m.;
- y_B livello dello strato di separazione, rispetto al l.m.m.;
- v_A velocità della corrente d'acqua dolce, positiva se diretta verso monte;
- v_B velocità della corrente d'acqua salata, positiva se di-

retta verso monte;

Q_A portata d'acqua dolce;

Q_B portata d'acqua salata;

B_A larghezza dello specchio liquido alla superficie;

B_B larghezza dello strato di separazione;

γ_A peso specifico dell'acqua dolce;

γ_B peso specifico dell'acqua salata;

i_A perdita d'energia per unità di peso e per unità di lunghezza del corso d'acqua, relativa allo strato d'acqua dolce;

i_B lo stesso per l'acqua salata;

g accelerazione di gravità.

Le equazioni (1) e (3) esprimono il bilancio energetico per le correnti d'acqua dolce e d'acqua salata; le equazioni (2) e (4) la conservazione delle rispettive masse (volumi).

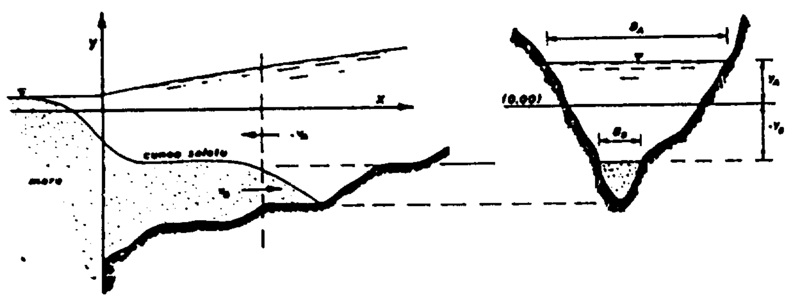


Fig.1 - Nomenclatura

Elaborando opportunamente le equazioni (1) e (3) si perviene alle seguenti equazioni, nelle quali compaiono le portate:

$$Q_A = v_A\,(A_A - A_B) \quad e \quad Q_B = v_B\,A_B$$

in luogo della velocità v_A e v_B:

$$\frac{\partial v_A}{\partial x}\left(1 - \frac{Q_A^2\,B_A}{g(A_A - A_B)^3}\right) + \frac{\partial v_B}{\partial x}\,\frac{Q_A^2\,B_B}{g(A_A - A_B)^3} + \frac{\partial Q_A}{\partial x}\,\frac{2Q_A}{g(A_A - A_B)^2} =$$

$$= i_A - \frac{1}{g(A_A - A_B)}\,\frac{\partial Q_A}{\partial t} \qquad (1')$$

$$\frac{\partial v_B}{\partial x}\left(\varepsilon - \frac{Q_B^2\,B_B}{g A_B^3}\right) + \frac{\partial v_A}{\partial x}(1-\varepsilon) + \frac{\partial Q_B}{\partial x}\,\frac{2\,Q_B}{g A_B^2} = i_B - \frac{1}{g A_B}\,\frac{\partial Q_B}{\partial x} \qquad (3')$$

Nell'equazione (3') è stata indicata con ε l'espressione $(1-\gamma_A/\gamma_B)$. A proposito dell'equazione (3') c'è da osservare che le variazioni della portata d'acqua salata nel tempo e nello spazio sono sempre molto piccole, per cui risultano trascurabili rispetto agli altri il terzo termine a primo membro e il secondo termine a secondo membro.

Le espressioni $\frac{Q_A^2\,B_A}{g(A_A - A_B)^3}$ e $\frac{Q_A^2\,B_B}{g(A_A - A_B)^3}$ rapppresentano i numeri di Froude al quadrato della corrente d'acqua dolce, rispettivamente riferiti alle larghezze B_A e B_B, essi sono entrambi molto piccoli rispetto all'unità, il che ci consente di porre uguale a 1 l'espressione dentro parentesi nel primo termine e di eliminare completamente il secondo termine della equazione (4'). Analogamente si porrà uguale a c l'espressione dentro parentesi nel primo membro dell'equazione (3').

Per quanto riguarda le espressioni delle perdite d'energia, analogamente a quanto fatto nella trattazione a moto permanente, esse assumono la forma generale:

$$i_A = -\frac{1}{8g}\, f\, v_A |v_A| \frac{(P_A - P_B)}{(A_A - A_B)} - \frac{1}{8g}\, f_s\, (v_A - v_B)|v_A - v_B| \frac{B_B}{(A_A - A_B)} \qquad (5)$$

$$i_B = -\frac{1}{8g}\, f_s v_B |v_B| \frac{P_B}{A_B} - \frac{1}{8g}\, f_s (v_B - v_A)|v_B - v_A| \frac{B_B}{A_A}\,, \qquad (6)$$

essendo f il coefficiente di resistenza sulle pareti dell'alveo nella formula di Darcy-Weisbach; f_s il coefficiente di resistenza sullo strato di separazione; A_A e A_B l'area liquida rispettivamente ai livelli y_A e y_B; P_A e P_B il contorno bagnato agli stessi livelli.

Poichè, però, la velocità v_B della corrente d'acqua salata è generalmente piccola in confronto alla velocità v_A della corrente d'acqua dolce, le espressioni (5) e (6) si riducono a:

$$i_A = -\frac{1}{8g}\, Q_A |Q_A| \frac{f(P_A - P_B) + f_s B_B}{(A_A - A_B)^3}\,, \qquad (5')$$

$$i_B = -\frac{1}{8g}\, f_s Q_A |Q_A| \frac{B_B}{A_B (A_A - A_B)^2} \qquad (6')$$

nelle quali si è introdotta la portata $Q_A = v_A \; (A_A - A_B)$.

3. RISOLUZIONE PER DIFFERENZE FINITE

E' possibile adesso risolvere il sistema di equazioni differenziali con un procedimento per differenze finite. Val la pena di osservare, innanzitutto, che avendo eliminato Q_B dalle equazioni (1') e (3'), tale sistema si riduce da quattro a tre equazioni.

Si consideri un tratto di fiume, a partire dalla foce, abbastanza lungo perchè nell' estremità di monte non si risentano praticamente gli effetti delle oscillazioni di marea; i fenomeni che si determinano entro questo tratto di fiume sono governati dalle due condizioni al contorno assegnate, indipendenti fra di loro: la portata d'acqua dolce che entra nella estremità di monte (costante o eventualmente variabile nel tempo) e l'oscillazione del livello che si stabilisce nella estremità di valle (dipendente dalle vicende di marea).

Si supponga ora il canale diviso in $(M-1)$ tronchi, ciascuno di lunghezza $(\Delta x)_m$ (con $m = 1, 2, \ldots\ldots, M-1$), lungo ognuno dei quali si assume una variazione lineare delle caratteristiche idrauliche e geometriche; richiamandoci alla Fig.2, denoteremo con l'indice m i parametri geometrici e idraulici della sezione m. Consideriamo poi tre successivi istanti di tempo $(t - \Delta t)$, t e $(t + \Delta t)$; contrassegneremo con un doppio apice le grandezze relative all'istante $(t - \Delta t)$, con un apice quelle relative all'istante $(t + \Delta t)$, mentre lasceremo senza alcun segno le grandezze relative all'istante t.

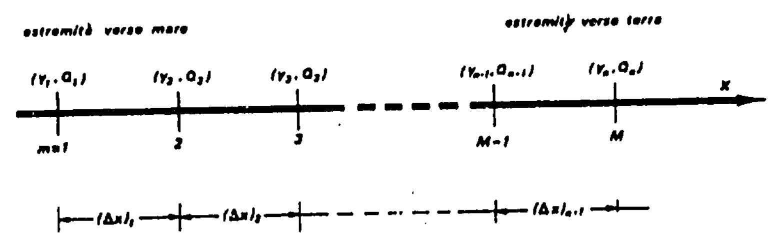


Fig.2 - Divisione in tronchi

La traduzione delle equazioni (1'), (2), (3') in forma di differenze finite, sarà fatta in accordo col seguente criterio. I rapporti differenziali spaziali, per le grandezze y_A e Q_A saranno riferiti all'istante $(t + \Delta t)$, mentre quelli per y_B saranno riferiti all'istante t. In conformità a ciò, i rapporti differenziali temporali, saranno riferiti all'intervallo di tempo compreso fra t e $(t + \Delta t)$ per le grandezze y_A e Q_A e all'intervallo di tempo fra $(t - \Delta t)$ e t per quanto riguarda y_B. Per quanto riguarda le grandezze finite, infine, esse saranno generalmente riferite all'istante t; le portate al quadrato che compaiono nei termini dissipativi, tuttavia, saranno espresse come prodotto $Q'_A\, Q_A$ il che permette di introdurre in forma lineare la portata al tempo $(t + \Delta t)$.

Il criterio esposto per il passaggio alle differenze finite, permette di risolvere con un procedimento esplicito la equazione (3'), comportando invece un procedimento implicito per la soluzione delle equazioni (1') e (2).

La scelta di un procedimento implicito, almeno per quanto riguarda la corrente d'acqua dolce, dà maggiori garanzie di stabilità per la soluzione numerica, senza dover ricorrere a intervalli d'integrazione Δt troppo piccoli. Il procedimento esplicito per il calcolo del cuneo salato, d'altra parte, si rende necessario dal momento che l'ampiezza del cuneo stesso è continuamente variabile, per cui non è possibile individuare a priori la condizione al contorno di monte.

Passando alle differenze finite con il criterio sopra indicato, le equazioni differenziali (1'), (2), (3') si trasformano nelle seguenti equazioni algebriche:

$$\frac{(y'_{Am+1} - y'_{Am})}{\Delta x_m} + \frac{(Q'_{Am+1} - Q'_{Am})}{\Delta x_m} \; \frac{(TA_m + TA_{m+1})}{2} =$$

$$= - \frac{(Q'_{Am} + Q'_{Am+1})}{2} \quad (TB_m + TB_{m+1}) -$$

$$- \frac{\frac{1}{2}\,(Q'_{Am} + Q'_{Am+1}) - \frac{1}{2}\,(Q_{Am} + Q_{m+1})}{\Delta t} \quad \frac{(TC_m + TC_{m+1})}{2}; \qquad (1")$$

$$\frac{(Q'_{Am+1} - Q'_{Am})}{\Delta x_m} + \frac{(B_{Am} + B_{Am+1})}{2} \; \frac{\frac{1}{2}(y'_{Am} + y'_{Am+1}) - \frac{1}{2}\,(y_{Am} + y_{Am+1})}{\Delta t} -$$

$$- \frac{(B_{Bm} + B_{Bm+1})}{2} \; \frac{\frac{1}{2}\,(y_{Bm} + y_{Bm+1}) - \frac{1}{2}\,(y''_{Bm} + y''_{Bm+1})}{\Delta t} = 0; \qquad (2")$$

$$\frac{(y_{Bm+1} - y_{Bm})}{\Delta x_m}\, \epsilon + \frac{(y_{Am+1} - y_{Am})}{\Delta x_m}\, (1 - \epsilon) =$$

$$= - \frac{(TD_m + TD_{m+1})}{2} \qquad (3")$$

Le espressioni TA, TB, TC, TD (introdotte per brevità di scrittura nelle equazioni appena scritte), sono funzioni della portata Q_A e dei livelli y_A e y_B che si stabiliscono in ciascuna sezione al tempo t:

$$TA = \frac{2Q_A}{g(A_A - A_B)^2} \qquad (7)$$

$$TB = \frac{1}{16\,g}\,|Q_A|\,\frac{f\,(P_A - P_B) + f_s\,B_B}{(A_A - A_B)^3} \tag{8}$$

$$TC = \frac{1}{g\,(A_A - A_B)} \tag{9}$$

$$TD = \frac{1}{8\,g}\,|Q_A|\,Q_A\,\frac{f_s\,B_B}{A_B(A_A - A_B)^2} \tag{10}$$

Introducendo i seguenti parametri (dipendenti dalle condizioni che si stabiliscono al tempo t nelle sezioni m e $m+1$ e quindi caratteristici del tronco m):

$$\eta_m = \frac{(TA_m + TB_{m+1})}{2} + \Delta x_m\,\frac{(TB_m + TB_{m+1})}{2} + \frac{\Delta x_m}{2\Delta t}\,\frac{(TC_m + TC_{m+1})}{2} \tag{11}$$

$$\theta_m = -\frac{(TA_m + TB_{m+1})}{2} + \Delta x_m\,\frac{(TB_m + TB_{m+1})}{2} + \frac{\Delta x_m}{2\Delta t}\,\frac{(TC_m + TC_{m+1})}{2} \tag{12}$$

$$\mu_m = \frac{\Delta x_m}{\Delta t}\,\frac{(Q_{Am} + Q_{Am+1})}{2}\,\frac{(TC_m + TC_{m+1})}{2} \tag{13}$$

$$\nu_m = \frac{\Delta x_m}{2\Delta t}\,\frac{(B_{Am} + B_{Am+1})}{2} \tag{14}$$

$$\xi_m = \frac{\Delta x_m}{\Delta t}\left[\frac{(B_{Bm} + B_{Bm+1})}{2}\,\frac{(y_{Bm} + y_{Bm+1}) - (y''_{Bm} + y''_{Bm+1})}{2} + \frac{(B_{Am} + B_{Am+1})}{2}\,\frac{(y_{Am} + y_{Am+1})}{2}\right] \tag{15}$$

Le equazioni algebriche (1"), (2") assumono la seguente forma, ancora più compatta:

$$y'_{m+1} - y'_m + \eta_m\,Q'_{Am+1} + \theta_m\,Q'_m = \mu_m \tag{1'''}$$

$$\nu_m(y'_{m+1} + y'_m) + Q'_{m+1} - Q'_m = \xi_m \tag{2'''}$$

Tali espressioni mettono in relazione fra di loro i livelli e le portate d'acqua dolce che si stabiliscono al tempo $(t + \Delta t)$ in due sezioni successive. Tali livelli e portate (contrassegnati con un apice) devono ritenersi incogniti, mentre sono da considerarsi noti i parametri η, θ, μ, ν, ξ (non segnati da apice), i quali dipendono dalle caratteristiche geometriche del tronco compreso fra le due sezioni nonchè dalle portate e livelli - sia d'acqua dolce sia d'acqua salata - che si stabiliscono nelle stesse sezioni al tempo t.

La risoluzione simultanea delle $2(M-1)$ equazioni come le (1") e (2") relative agli $(M-1)$ tronchi che costituiscono il campo di moto, associate alle due condizioni al contorno che si impongono alle estremità, fornisce il richiesto andamento dei livelli e delle portate y_A e Q_A lungo il fiume, al tempo $(t + \Delta t)$.

Tale soluzione può essere ottenuta, attraverso l'eliminazione delle incognite nelle sezioni intermedie, mettendo in diretta relazione le condizioni di livello e portata che si stabiliscono nell'estremità di valle del fiume (in cui è assegnato, in ciascun istante, il livello in mare y_A), con quelle che si stabiliscono nell'estremità di monte (in cui è assegnata, in ciascun istante, la portata in arrivo Q_A).

Impiegando tale tecnica (particolarmente adatta al calcolo automatico e già ampiamente collaudata [3], [4]) si ottiene il seguente gruppo di equazioni ricorrenti, equivalente al sistema di equazioni (1"') e (2"'):

$$q_{m-1} = \frac{1}{p_{m-1} + \theta_{m-1}} \qquad (16)$$

$$t_{m-1} = \frac{\eta_{m-1}}{p_{m-1} + \theta_{m-1}} \qquad (17)$$

$$s_{m-1} = \frac{r_{m-1} + \mu_{m-1}}{p_{m-1} + \theta_{m-1}} \qquad (18)$$

$$\sigma_{m-1} = p_{m-1} \, \nu_{m-1} + 1 \qquad (19)$$

$$p_m = \frac{\sigma_{m-1} \, t_{m-1} + 1}{\sigma_{m-1} \, q_{m-1} + \nu_{m-1}} \qquad (20)$$

$$r_m = \frac{\xi_{m-1} + \sigma_{m-1} \, s_{m-1} - \nu_{m-1} \, r_{m-1}}{\sigma_{m-1} \, q_{m-1} + \nu_{m-1}} \qquad (21)$$

$$y'_{Am} = - p_m \, Q_{Am} + r_m \qquad (22)$$

$$Q'_{Am-1} = - q_{m-1} \, y'_{AM} - t_{m-1} \, Q'_{Am} + s_{m-1} \qquad (23)$$

Per $m = 1$ (sezione iniziale, a mare) valgono le seguenti espressioni per p ed r:

$$p_1 = 0 \qquad (24)$$

$$r_1 = y'_{A1} \qquad (25)$$

Alle equazioni precedenti, naturalmente va associata la (3"), la quale fornisce subito il livello dell'acqua salata y_B che si stabilisce nelle successive sezioni del fiume, a partire dalla sezione a mare $(m = 1)$, note che siano le portate ed i livelli d'acqua dolce:

$$y_{Bm+1} = y_{Bm} + \frac{1-\varepsilon}{\varepsilon} (y_{Am} - y_{Am+1}) + \frac{\Delta x_m}{\varepsilon} \frac{(TD_m + TD_{m+1})}{2} \qquad (26)$$

4. CONDIZIONI INIZIALI E CONDIZIONI AL CONTORNO

Le condizioni iniziali del fiume possono determinarsi a partire da un ipotetico stato di moto permanente, immaginando che per $t \leq 0$ il livello in mare sia fisso e che la portata d'acqua dolce proveniente da monte sia costante. La risoluzione del problema in moto permanente si ottiene facilmente dal sistema di equazioni (1"), (3"), nelle quali, ovviamente, va posto:

$$Q'_{Am+1} = Q'_{Am} = Q_{Am+1} = Q_{Am} = Q$$

$$y'_{Am+1} = y_{Am+1}; \; y'_{Am} = y_{Am}$$

Assegnata la portata costante Q, il sistema può risolversi per tentativi rispetto alle due incognite y_{Am+1} e y_{Bm+1}; procedendo da valle verso monte e supponendo quindi già noti i valori nelle sezioni precedenti y_{Am} e y_{Bm}.

Naturalmente tale stato permanente non corrisponde generalmente ad una situazione reale, poichè tanto il mare, quanto la portata in arrivo sono in generale soggetti a continue escursioni. E' possibile constatare tuttavia, che gli effetti delle condizioni iniziali si riflettono sulle condizioni successive del corso d'acqua solo per alcune ore; cosicchè è sufficiente iniziare il calcolo con alcune ore di anticipo rispetto alla situazione da esaminare perchè i risultati in quest'ultimo intervallo di tempo siano corretti.

Un'osservazione va fatta intorno alle condizioni al contorno che si stabiliscono nella sezione d'estremità a mare $(m = 1)$ e nella sezione d'estremità a monte $(m = M)$.

Nell'estremità a monte (la quale è scelta, come s'è detto, abbastanza lontana dalla foce, affinchè non risenta gli effetti delle escursioni del mare e non sia mai raggiunta dal cuneo salino), la sezione del fiume è sempre interamente occupata dall'acqua dolce, cosicchè la condizione da imporre è

semplicemente quella della portata Q_A in arrivo (questa sarà perciò sempre negativa, cioè diretta verso valle).

Nell'estremità a mare, invece, si possono avere tre condizioni al contorno diverse:

a) La sezione di sbocco (Fig.3) è interamente occupata dalla acqua dolce, cioè il cuneo salino è ricacciato in mare. Tale situazione si ha sempre durante le forti piene e può aversi temporaneamente anche durante le morbide, nella fase di marea calante. In questo caso il fiume è interessato dalla sola corrente d'acqua dolce: la condizione al contorno è costituita dal livello y_A alla foce (pari al livello del mare), e il moto è governato dalle sole equazioni (1) e (2).

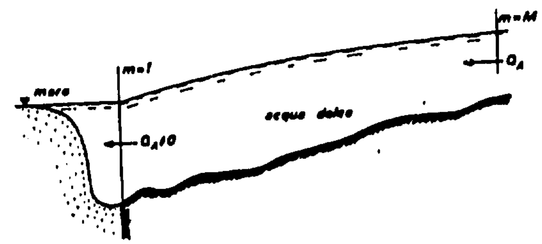
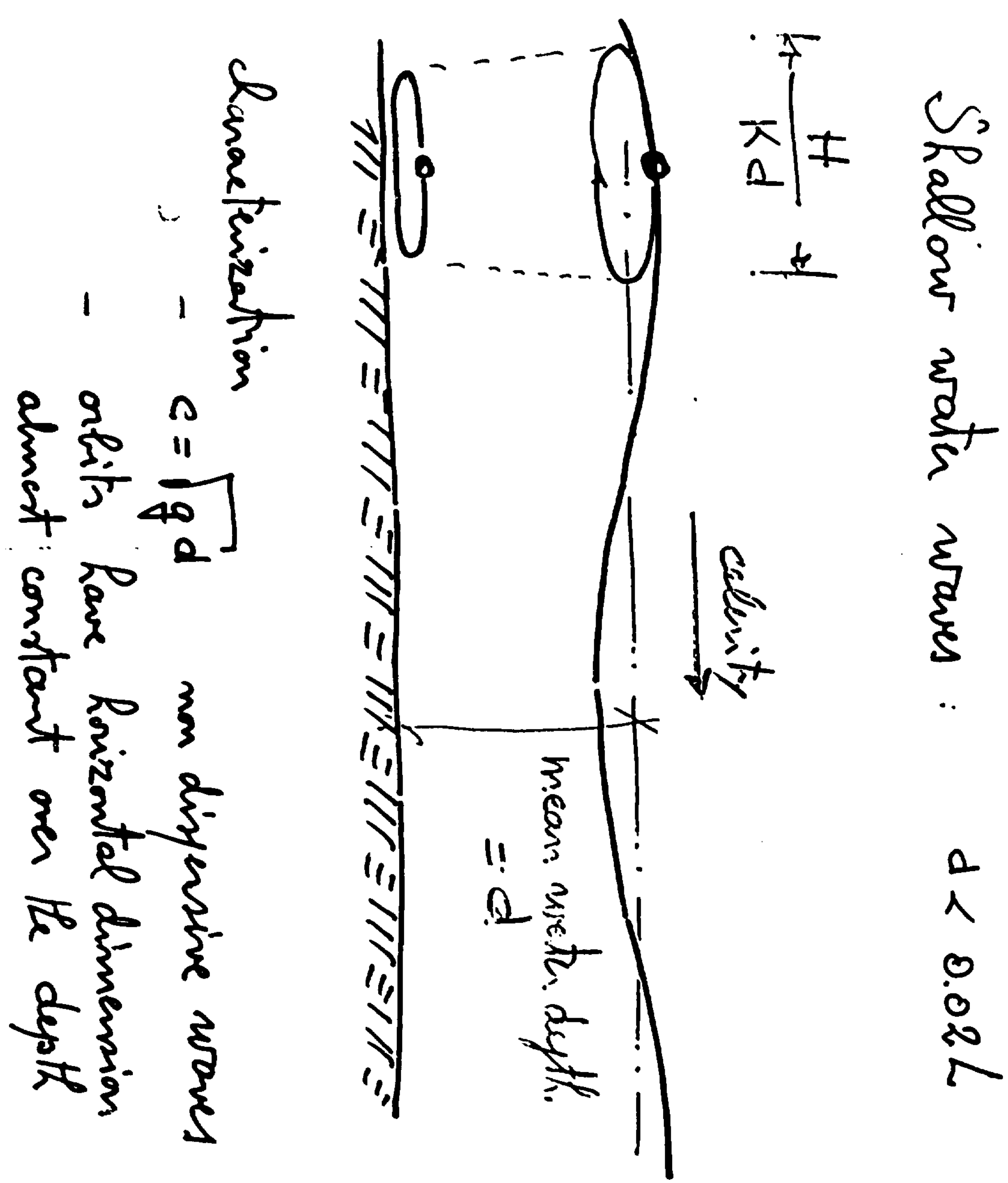


Fig.3 - Cuneo ricacciato in mare

b) La sezione di sbocco (Fig.4) è interessata superiormente dall'acqua dolce affluente (portata sempre negativa) e inferiormente dall'acqua salata (portata positiva, cioè diretta verso monte, se il cuneo salino sta risalendo, o negativa, cioè diretta verso valle, se il cuneo salino sta ritirandosi). In questo caso è possibile distinguere due tratti del fiume: quello più a valle, interessato dal cuneo salino, in cui il moto delle due correnti, dolce e salata, è governato da tutte e quattro le equazioni (1),(2), (3), (4) e un tratto più a monte in cui il moto della sola



acqua dolce è governato dalle sole equazioni (1), (2). Si ricorda che nella presente trattazione, avendosi trascurato la velocità della corrente d'acqua salata, le equazioni in gioco sono solo tre. Nella sezione di sbocco, in ogni

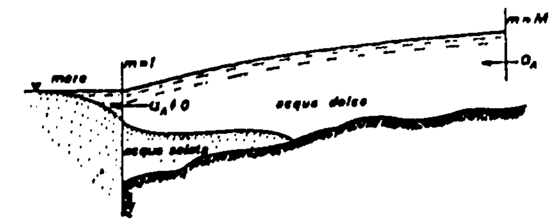


Fig.4 - Intrusione del cuneo

modo, la condizione al contorno per il livello dell'acqua dolce y_A è ancora il livello del mare, mentre per il livello dell'acqua salata sarà da imporsi (vedi par.5) la condizione *critica relativa*, cioè quel livello y_B tale che sia:

$$F_R = \frac{Q_A \left[\epsilon\ B_A + (1-\epsilon)\ B_B \right]}{\epsilon g\ (A_A - A_B)^3} \qquad (27)$$

c) La sezione di sbocco (Fig.5) è completamente interessata dall'acqua salata, cioè il mare ha parzialmente invaso l'alveo fluviale. Ciò si verifica, con basse portate d'acqua dolce in arrivo, durante la fase di marea crescente. In questo caso la portata d'acqua dolce è negativa (cioè diretta verso valle) nella parte più a monte del fiume, ma si annulla prima di raggiungere la foce. E' possibile quindi distinguere tre tratti del fiume: quello più a valle, interessato dalla sola corrente salata, governata a rigore dalle equazioni (3), (4) ma non considerata nella presente trattazione; un tratto intermedio, interessato da una doppia corrente descritta da tutte e quattro le equazioni (so-

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Fig.5

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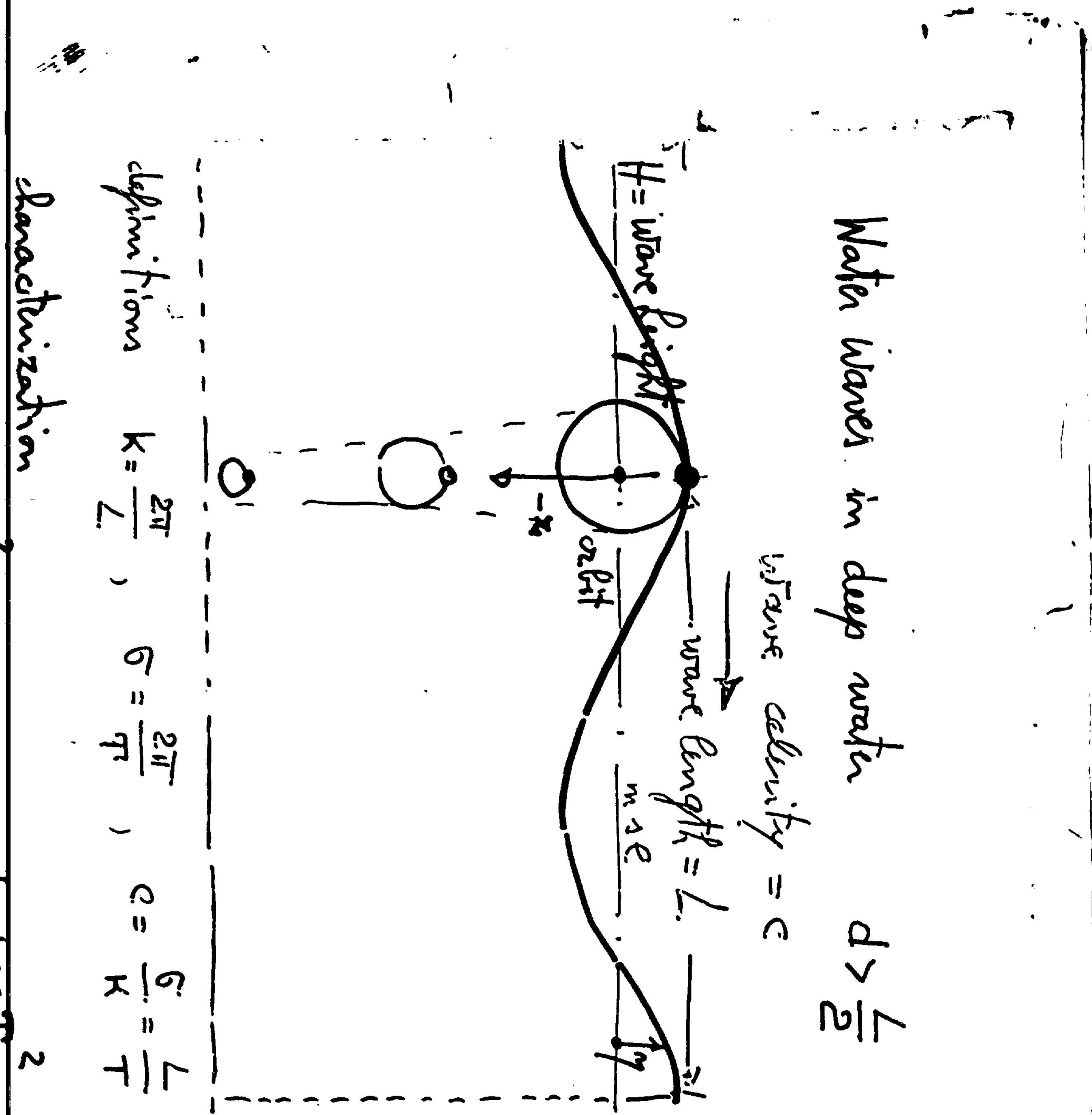


vo estremamente piccolo (p. es. -0,001 m³/s) che corrisponda in pratica ad una portata nulla; lo stesso sarà fatto in tutte le sezioni più a valle. I rispettivi livelli y_A saranno invece posti uguali al livello in mare.

5. CONDIZIONI CRITICHE RELATIVE

Si è già accennato nel paragrafo precedente alle condizioni *critiche relative* che si stabiliscono nella sezione di sbocco del fiume, e che costituiscono l'indispensabile condizione al contorno del campo di moto nella sua estremità verso mare.

Lo stabilirsi delle condizioni critiche alla foce corrisponde all'ipotesi che la corrente d'acqua dolce defluisca in mare assumendo il contenuto energetico minimo, compatibilmente con l'assegnata portata in arrivo e con l'assegnato livello del mare.

Se si suppone il cuneo salato, praticamente fermo (regime permanente, oppure, conformemente alle ipotesi assunte, velocità molto piccola per la corrente salata) , l'energia E_B dello strato d'acqua salata è esclusivamente sotto forma d'energia potenziale, ed è uguale al livello in mare y_M:

$$E_B = y_B + \frac{\gamma_A}{\gamma_B}(y_A - y_B) = y_M = costante \qquad (28)$$

L'energia E_A della corrente d'acqua dolce, d'altra parte, è sia potenziale sia cinetica, cioè:

$$E_A = y_A + \frac{Q_A^2}{2g\,(A_A - A_B)^2} \qquad (29)$$

Derivando l'espressione (29) rispetto ad $A = (A_A - A_B)$ ed

eguagliando a zero, si ott

$$\frac{dE_A}{dA} =$$

Poichè d'altra parte:

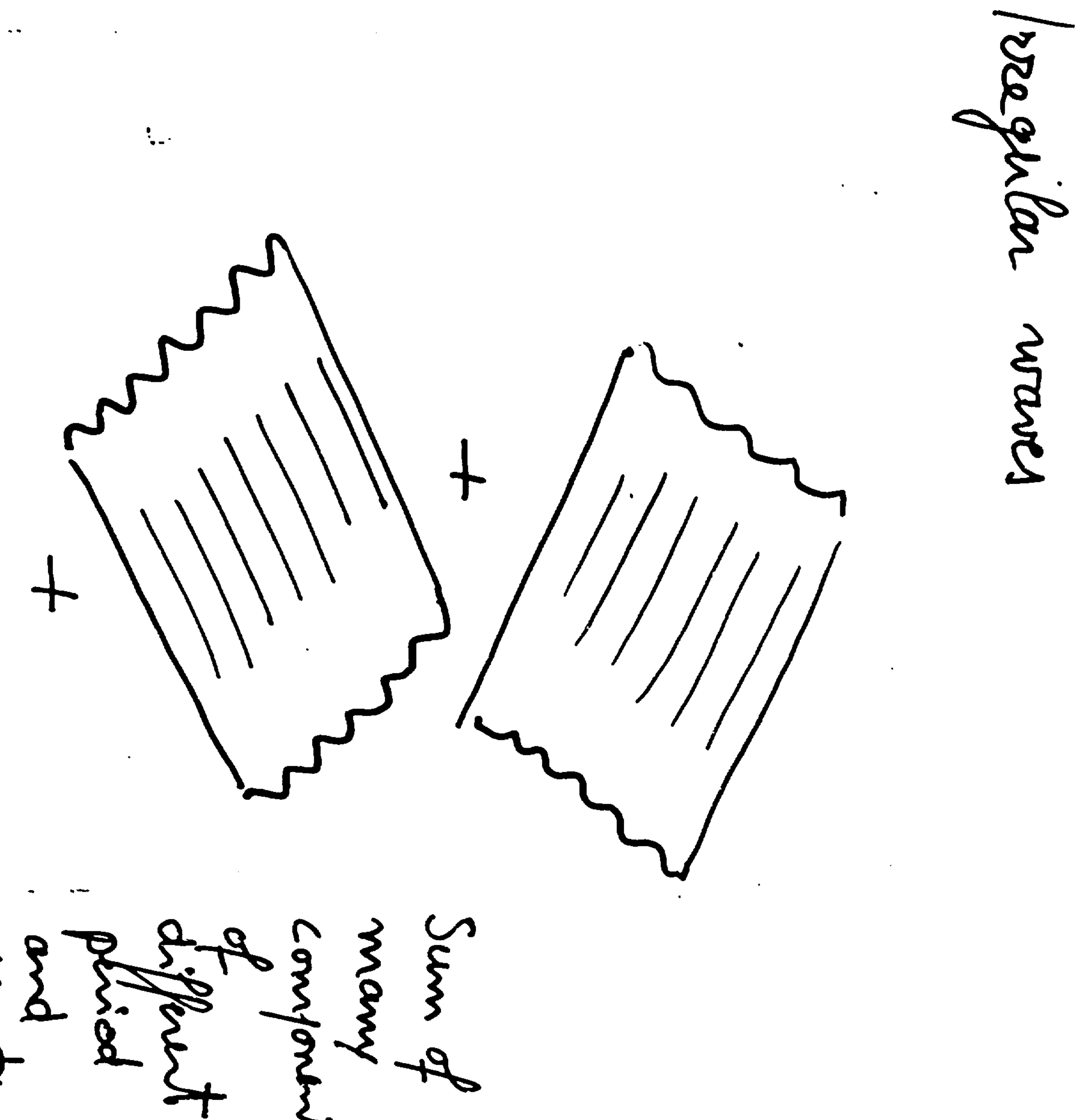
$$dA =$$

l'equazione (30) diventa:

$$(1 + \ldots$$

Sostituito nell'espre
ricavato derivando la (2
(27), esprimente le condi
sumere la corrente di acq

Giova osservare che l
no non solo nella sezione
energia richiesta dalle c
uguale al valore minimo d
carsi sempre alla foce, q
sempre inferiore a quella
stabilirsi anche in sezio
tà si presenta abbastanza
fase ascendente della mar
sta nel programma di calc
le condizioni critiche le
dono in difetto.



6. ORGANIZZAZIONE DEL PROGRAMMA DI CALCOLO

I dati d'ingresso del programma sono:

a) Configurazione geometrica del fiume: forma delle successive sezioni a partire da valle (per il calcolo di A, B, P), nonchè distanza fra l'una e l'altra $(\Delta x)_m$.

b) Condizioni al contorno a monte: andamento nel tempo della portata in arrivo, $Q_{AN}(t)$.

c) Condizione al contorno a valle: andamento nel tempo dei livelli in mare, $y_{A1}(t)$.

d) Caratteristiche fisiche delle due correnti: γ_A, γ_B, f e f_s.

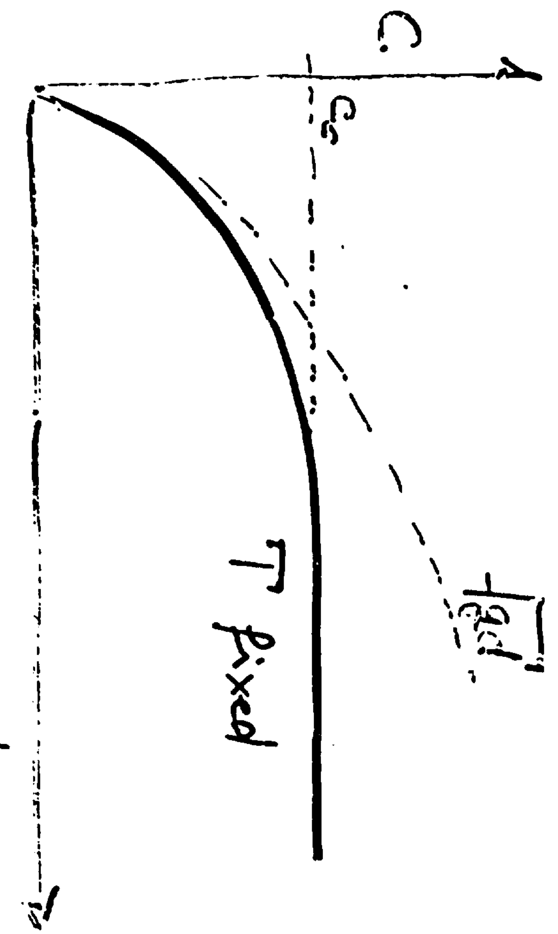
Le *condizioni iniziali* sono preventivamente calcolate e memorizzate per mezzo dell'apposito sottoprogramma in regime permanente. Tale sottoprogramma genera per $t = 0$ valori di y_{Am} e y_{Bm} $(m = 1, 2, \ldots\ldots M)$.

La *successione di calcolo* prevista per ogni intervallo successivo di tempo, consiste nel percorrere due volte l'intera lunghezza del corso d'acqua, la prima passando da una sezione all'altra a partire dal mare e procedendo verso terra, la seconda ripercorrendo tutte le sezioni da terra verso il mare. Ogni volta si eseguono le seguenti operazioni:

SPAZZATA DA MARE A TERRA $(m = 1, 2 \ldots\ldots\ldots M)$.

a) Calcolo e memorizzazione di y_{B1} nella sezione iniziale, utilizzando l'equazione (27), sulla base dei valori y_{A1} e Q_{A1} calcolati nell'istante precedente. Se y_{B1} risulta inferiore al fondo significa che il cuneo salino è ricacciato.

b) Calcolo della funzione TD_m e TD_{m+1} (eq. 10).



dispersion relation

$$\sigma^2 = gk\,\mathrm{tgh}\,kd$$

$$c = \frac{\sigma}{k} = \frac{g}{\sigma}\,\mathrm{tgh}\,kd$$

SOTTOPROGRAMMI SPECIALI

Per agevolare e accelerare i calcoli sono stati previsti speciali sottoprogrammi per il calcolo dei valori dell'area A, della larghezza B, e del perimetro bagnato P, in funzione del livello y, ad intervalli costanti nelle diverse sezioni. Le relative funzioni, calcolate una volta per tutte all'inizio del programma, saranno tenute in memoria e utilizzate tramite interpolazione per i valori calcolati di y.

7. APPLICAZIONI ALLA FOCE DELL'ADIGE

Numerosi rilievi di salinità condotti saltuariamente alla foce dell'Adige (i primi risalgono al 1913 [5]) indicano che la corrente di acqua dolce e la sottostante corrente d'acqua salata presentano una ben definita stratificazione anche in condizioni di modesta portata e di notevoli escursioni di marea.

Risulta, d'altra parte, che l'intrusione verso monte del cuneo risente in maniera determinante della configurazione geometrica del tratto di fiume presso la foce, la quale si presenta assai irregolare sia come planimetria (Fig.6), sia come profilo di fondo. E' stato quindi necessario introdurre

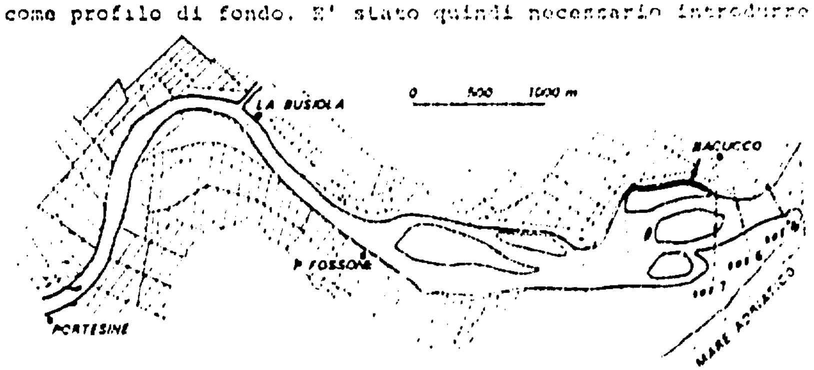
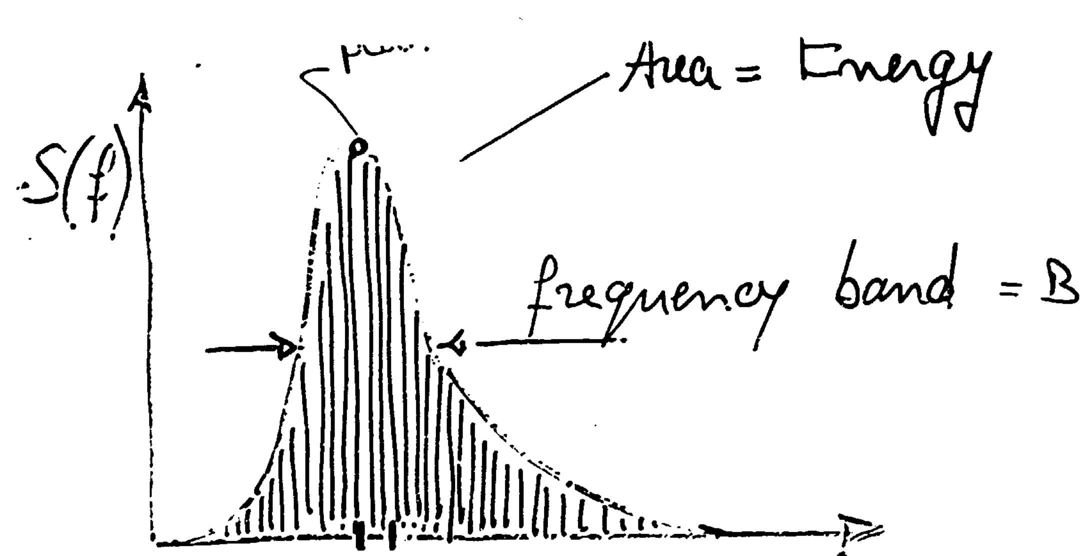


Fig.6 - Tratto terminale dell'Adige - Sezioni di misura.



$$f_m = \frac{1}{E} \int f \, S(f) \, df = 1/T_m$$

$$f_p = 1/T_p$$

A homogeneous sea state has normally a narrow band $B \ll f_m$

A heterogeneous sea state is frequently doubly peaked

Since different components are orthogonal
i.e. $\langle \eta_i , \eta_j \rangle = 0$ if $i \neq j$

$$E = \langle \eta^2 \rangle = \sum_i \langle \eta_i^2 \rangle = \sum_i H_i^2/8$$

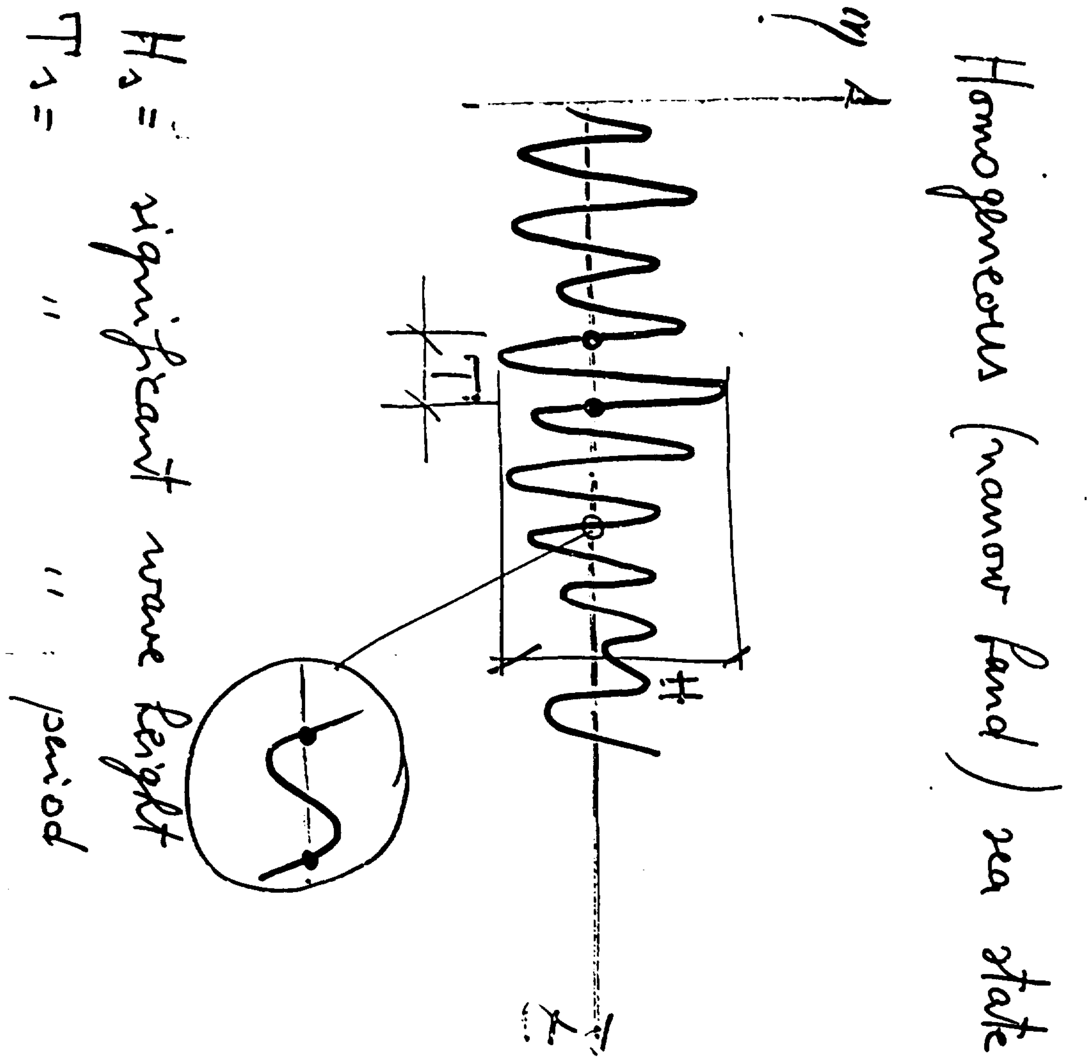
The distribution function of energy over the components is called

Spectral distribution

Normally the parameters characterizing the component space are

frequency $f = 1/T$

direction ϑ



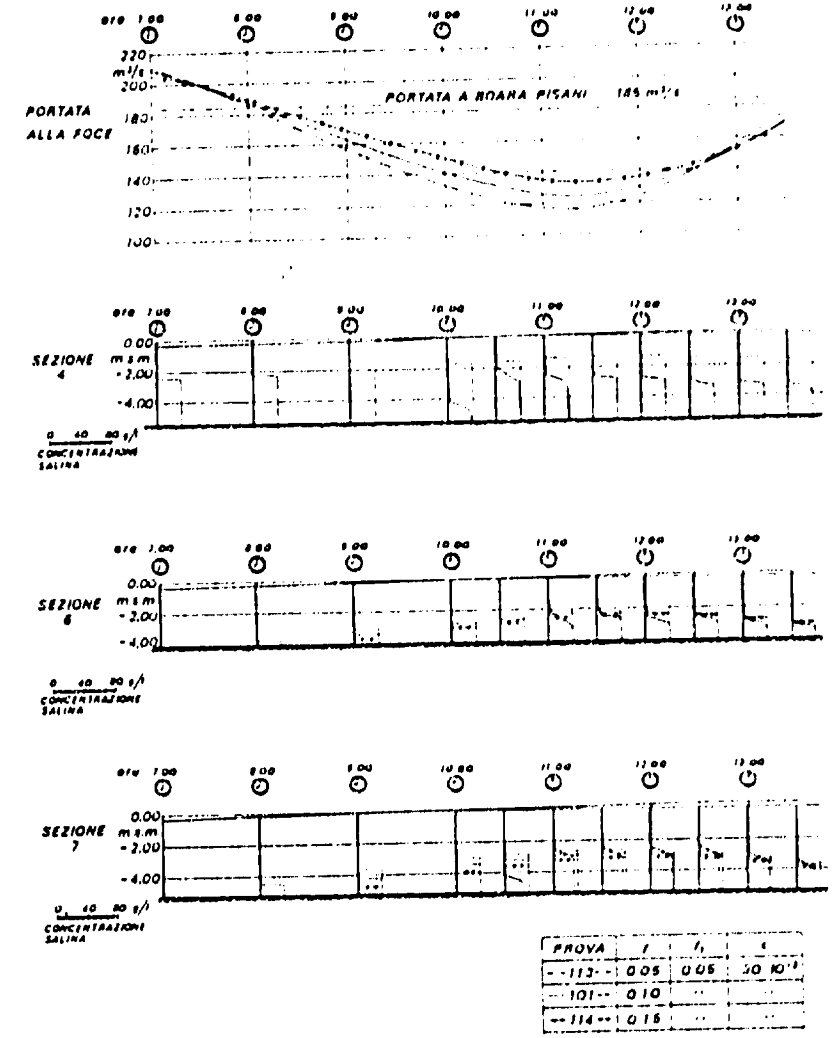


Fig.9 - Effetti del coefficiente di resistenza dell'alveo f.

tuvia, la cui ...
dell'alveo si è rivelat
del fenomeno in condizi
portata d'acqua dolce a
tà minima alla foce nel
lori molto bassi e ...
caso la corretta valuta
que del coefficiente f
venta molto importante
cuneo salato.

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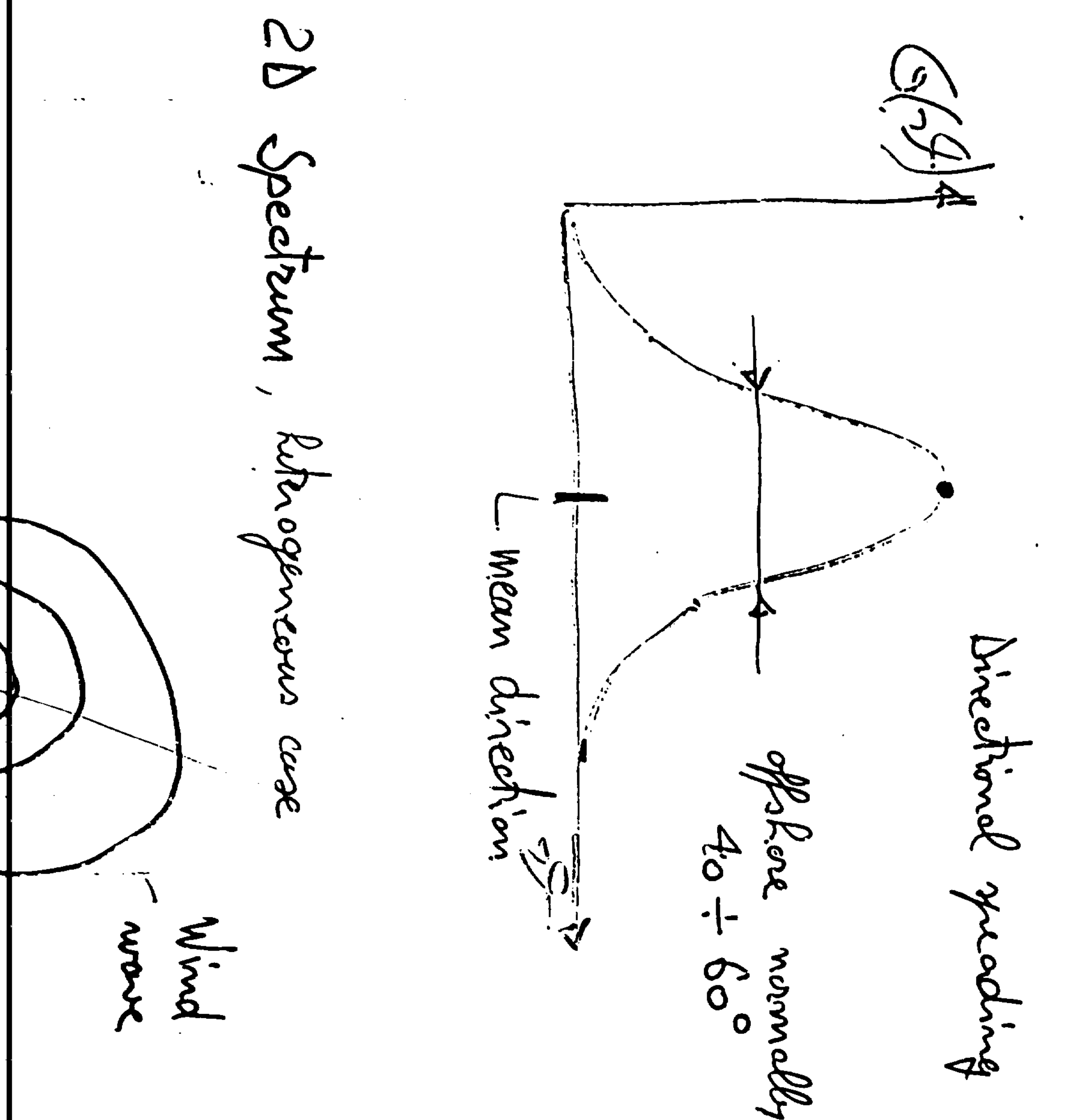
D'ALPAOS L. ...



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Probable maximum wave height

N = number of waves

$H_{max} \simeq H_s \sqrt{\frac{\ln N}{2}}$

Storm 3 hrs : N=1000 ⇒ $\frac{H_{max}}{H_s} = 1.86$

24 hrs : 8000 $= 2.1$[illegible]

$H_{max} \simeq 2 H_s$

$Freq\left(H > H_s\right) = 0.133 \simeq 1/7 \div 8$

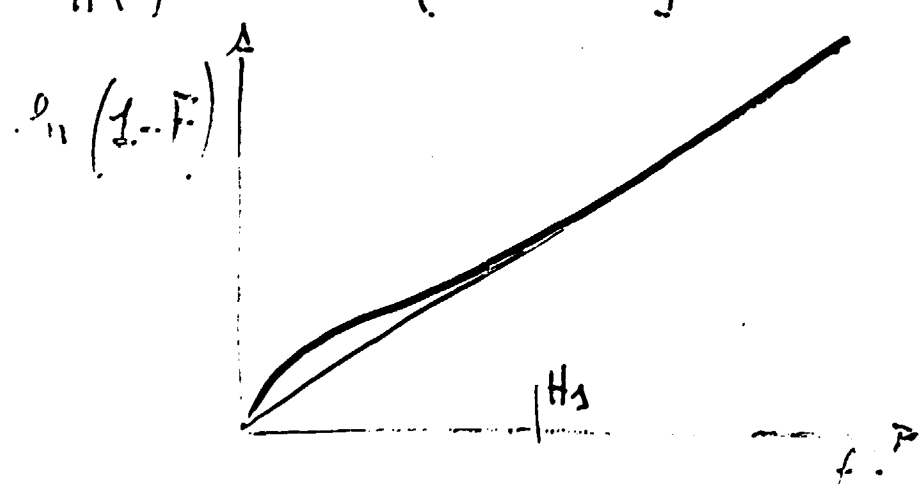
Hs is <u>not</u> a central value of the H distribution

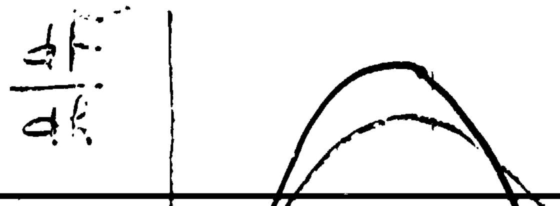
Contents

Wave height distribution

Rayleigh: $F_H(h) = 1 - e^{-\frac{2.0 h^2}{H_s^2}}$

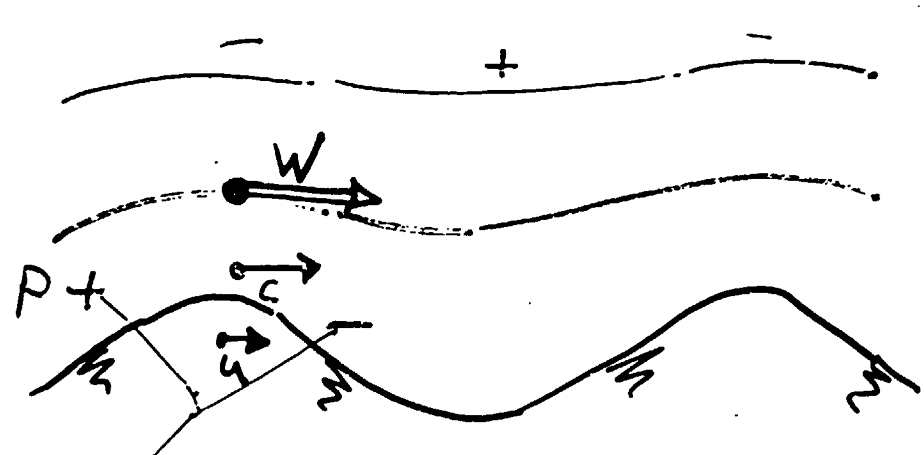
$F_H(h) = \text{Prob}\{ H \leq h \}$





The evolution over geologic time scale
is controlled by
vertical movements
of sea level and earth crust

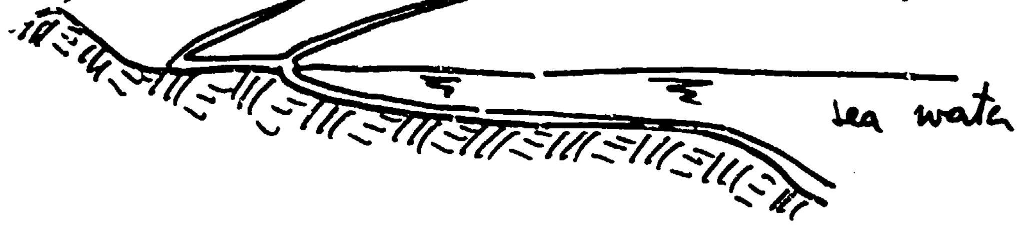
Wind waves



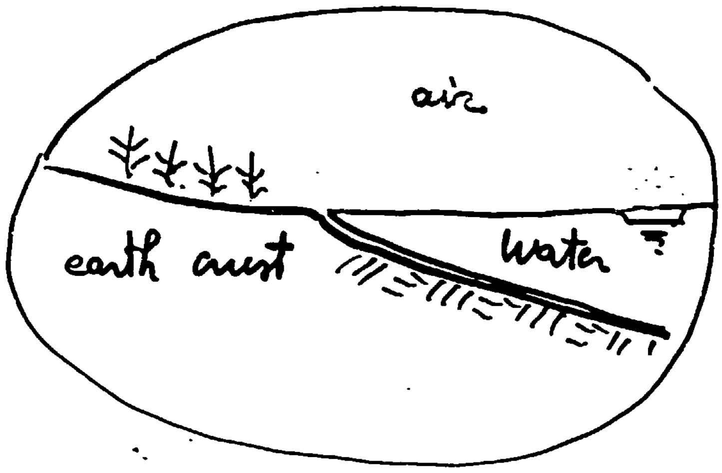
friction or sheltering effect

+ sheltering effect: most effective on short waves, increases wave energy

wave - wave non linear resonant



Coastal environment



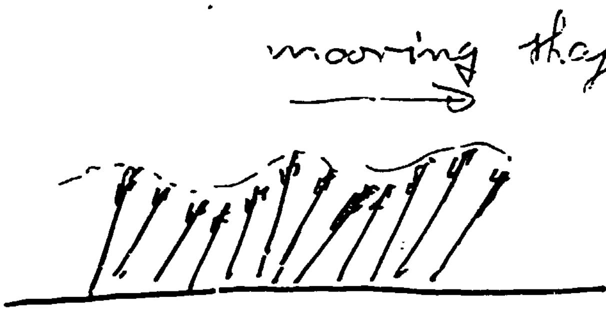
Wave generation

Most waves and invariably the highest waves are generated by <u>wind</u>

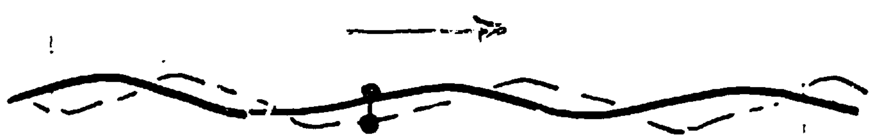
Other causes of waves are:

- ships (mooving ones)
- earthquakes (tsunami)

Waves. : mooving shape



particles move
parallel to
the shape mov. :
longitudinal or
compression waves

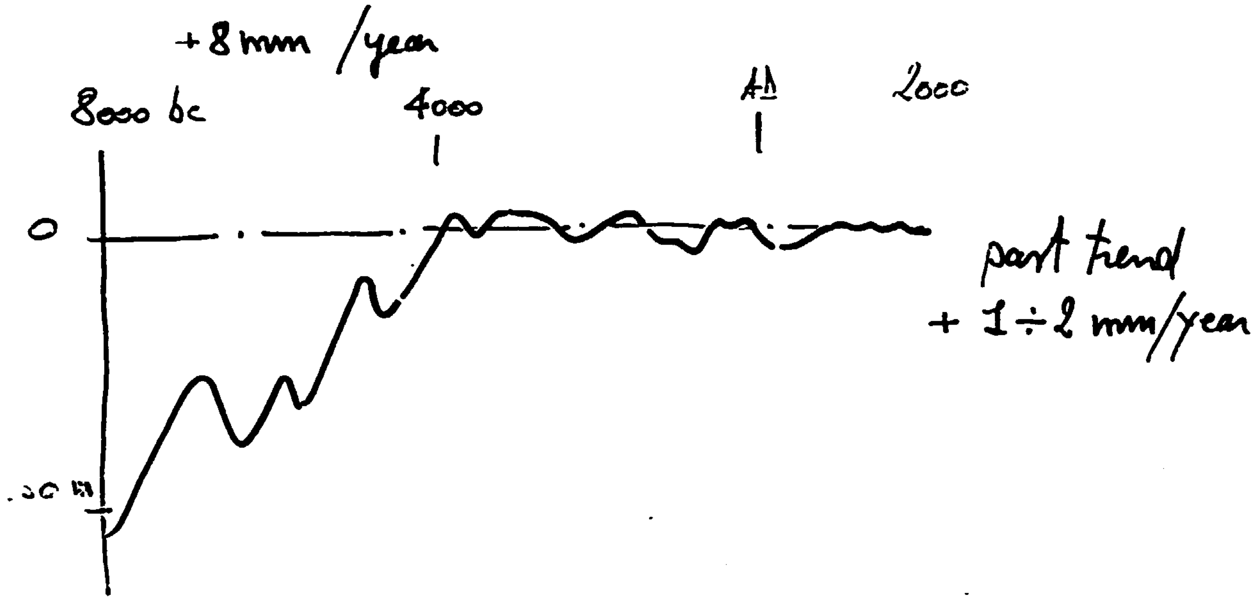


particles move in a
transversal direction

essential features:

- inertia
- elastic force recalling particles
  to the equilibrium position

  for surface water waves : gravity + pressure.



as a consequence of green-house effect
future trend 2-10 mm/year
most likely trend in 100 years
6 mm/year

Subsidence

Natural subsidence of young sedimentary deposits 2-5 mm/year

As a consequence of human activity (water, gas, oil mining).
> 1.0 cm/year.

Wave propagation

In deep water waves propagate along straight lines (lines of minimum length, maximum circles on the earth surface).

The velocity of propagation of wave agitation is the group celerity

$$\underset{m/s}{C_g} = 0.78 \underset{s}{T}$$

Long waves run quicker and arrive earlier than short waves
Long low waves announce the arrival of far generated storms.
The time rate of increase of frequency is proportional to the distance of the generation area

$$\frac{df}{dt} = \frac{4\pi}{g} e$$

Hindcasting methods

Physically based: integrate the radiation energy balance accounting for wave energy transport and for the mentioned source terms. E.g. SWAM.

Dimensional empirical approach, mostly used in engineering practice. E.g. SMB.

$$\frac{g H_s}{W^2} = \text{function}\left(\frac{gF}{W^2}\right)$$

$$\frac{g T_s}{W} = \text{function}\left(\frac{gF}{W^2}\right)$$

F = fetch : length of the way that wind and waves are going together

Essential hypotheses:

- Wind is constant over the fetch
- The generation area is wide and regular (a unique length parameter characterizes it.)

Extreme waves statistics

To be used for the design of structures, aiming to define the maximum wave load on the structure during its lifetime

- Collect wave data in the area or hindcast the major storms.
- The covered period should be at least 20 years long; don't trust short periods, cycles of several years in meteorological phenomena were recognized yet in the bible.
- Identify the major events. Their number should not be less than 30.
- Choose a frequency distribution shape (Fuller, Weibull, Gumbel..)
- Plot the data according to some rule

  e.g $P = \frac{2r-1}{2n}$ (Hazen)

  and control the distribution fitting
- Evaluate the parameters according to an efficient method.

Wave climate

Frequency distribution of wave characteristics (H_s, T_s), usually given for separate sectors, and sometimes for separate seasons.

Useful for

- evaluating the frequency of operation-no-operation conditions for a harbour, an offshore terminal, a construction yard, etc..
- evaluating sediment transport and, more generally, the behaviour of a system responding to frequent ~~low~~ medium height waves

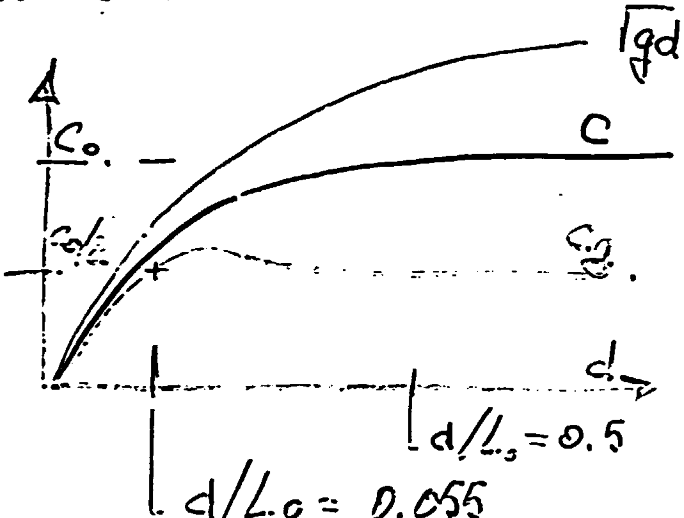
The frequency of the effective event is rather high: 1 day – 1 month / year

10 years of data are normally sufficient.

No statistical extrapolation is necessary.

Wave shoaling and refraction

Wave celerity is an increasing function of depth up to $d = L/2$. The group velocity shows a similar behaviour



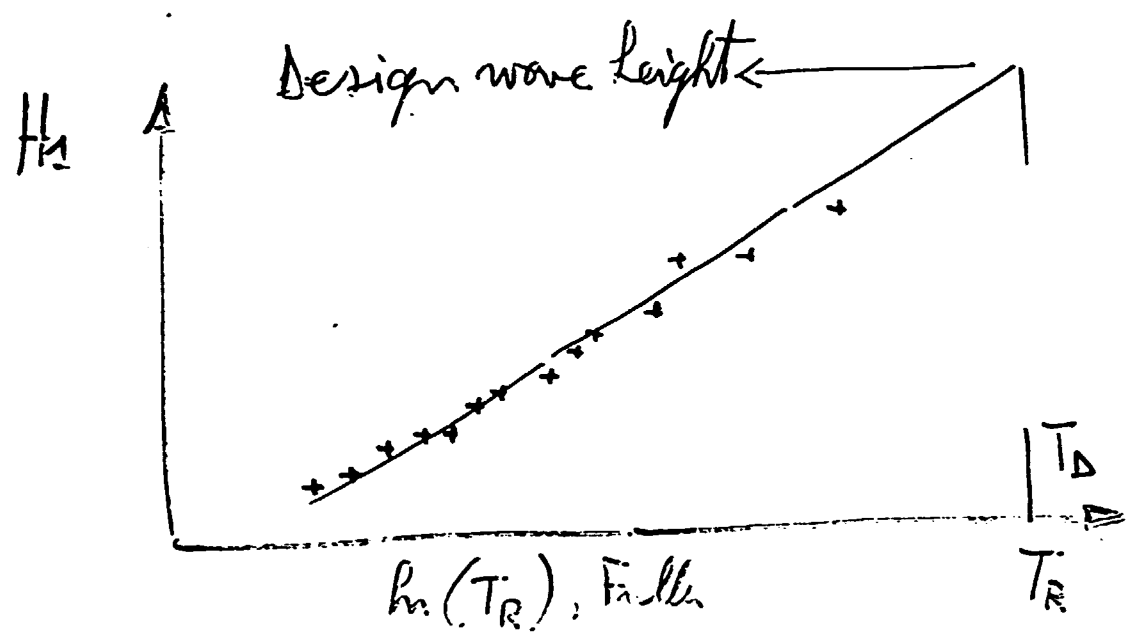
Wave period is constant along the propagation

Wave energy is almost constant offshore the breaker line

In a wave channel or for waves approaching the shore orthogonally

$$\text{energy flux} = E\, c_g = \frac{H^2}{8}\, c_g = \text{cost}$$

$$\frac{H}{H_o} = \sqrt{\frac{c_{go}}{c_g}} \equiv \text{shoaling coefficient}$$



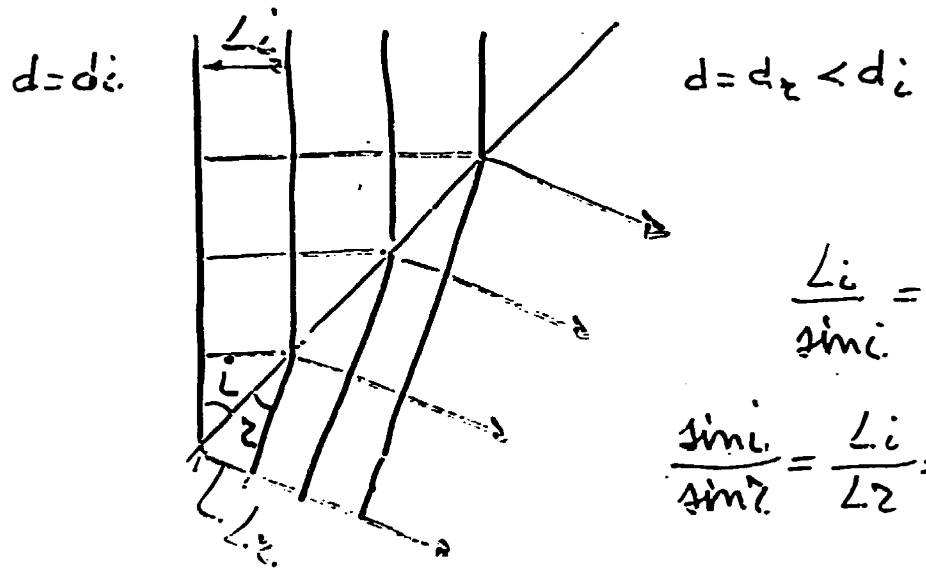
- Evaluate the return period of the design event from the lifetime L and the failure probability P_f

$$T_D = \frac{L}{-\ln(1-P_f)}$$

an the corresponding design wave height

Remark that $T_D = 20 \div 2000$ year and normally $100 \div 500$ year.
Relevant extrapolation is the norm.

If wave front form an angle with depth contour line waves turn toward the lower depth (refraction).



$$\frac{L_i}{\sin i} = \frac{L_z}{\sin z}$$

$$\frac{\sin i}{\sin z} = \frac{L_i}{L_z} = \frac{C_i}{C_z}$$

$$\frac{b_i}{\cos i} = \frac{b_z}{\cos z} \rightarrow \frac{b_i}{b_z} = \frac{\cos i}{\cos z}$$

From the conservation of energy between wave rays

$$E_i \, c_{g_i} \, b_i = E_z \, c_{g_z} \, b_z$$

$$\frac{H_z}{H_i} = \sqrt{\frac{c_{g_i}}{c_{g_z}} \cdot \frac{b_i}{b_z}} = K_1 \cdot K_z$$

Shoaling waves become steeper and steeper and shall eventually break

Breaking criterium

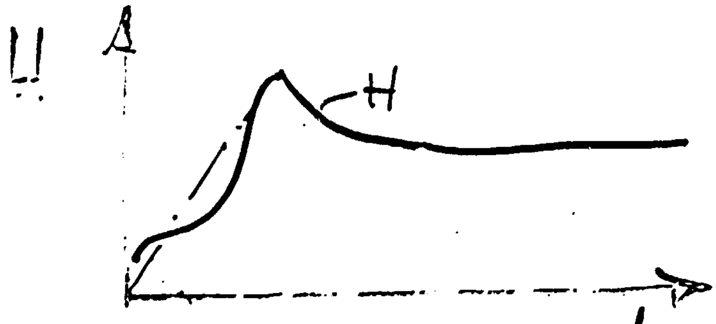
$H/L = 0.14$ in deep water

$H/d = 0.78$ in shallow water

$H/L = 0.14 \, tgh \, (Kd)$ Miche criterium

Actually breaking is not an instantaneous process. The breaker respond with some delay. (beach slope effect).

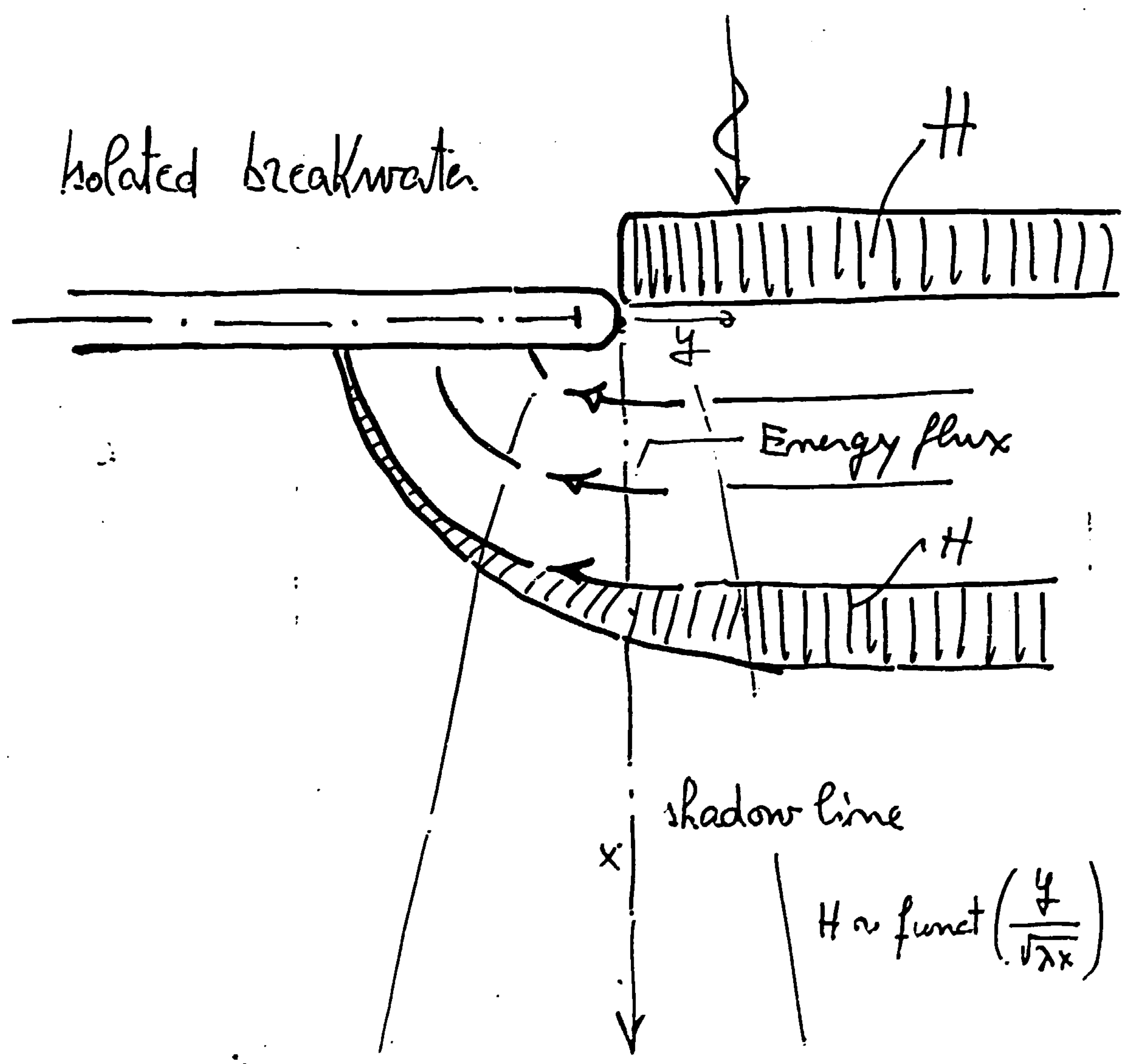
In the breaker zone wave height is almost proportional to depth, if depth is regularly decreasing

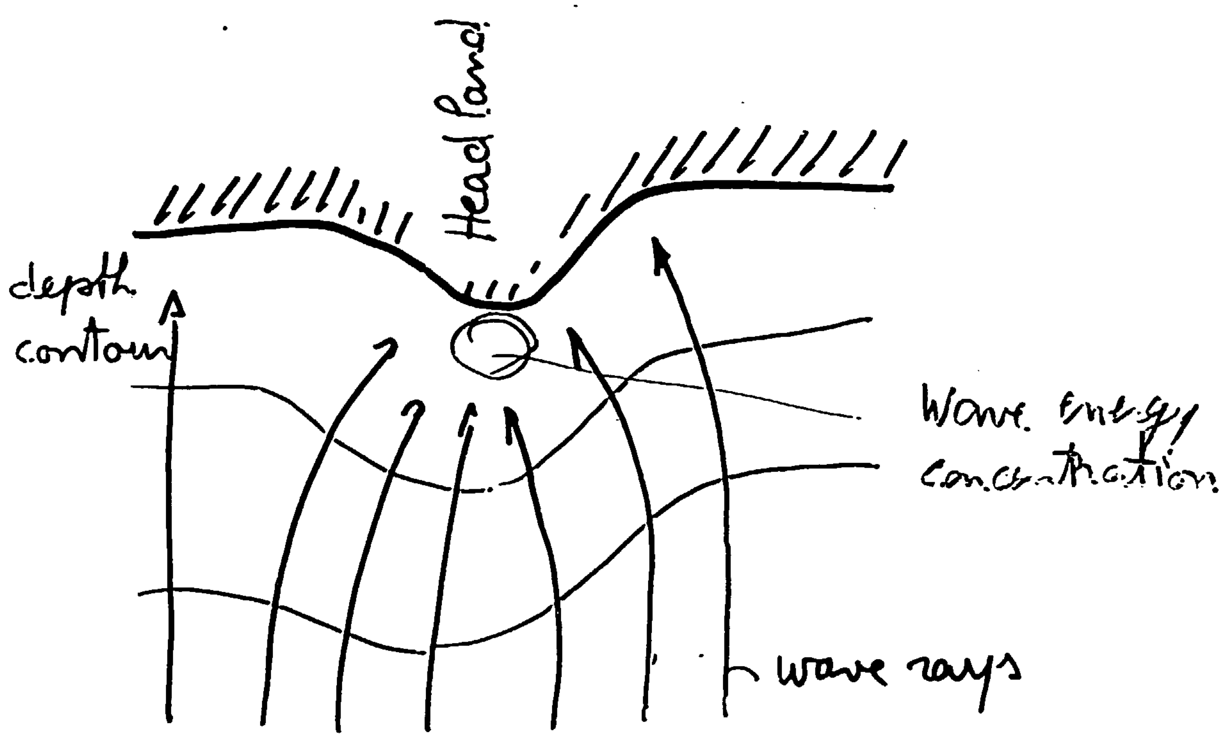


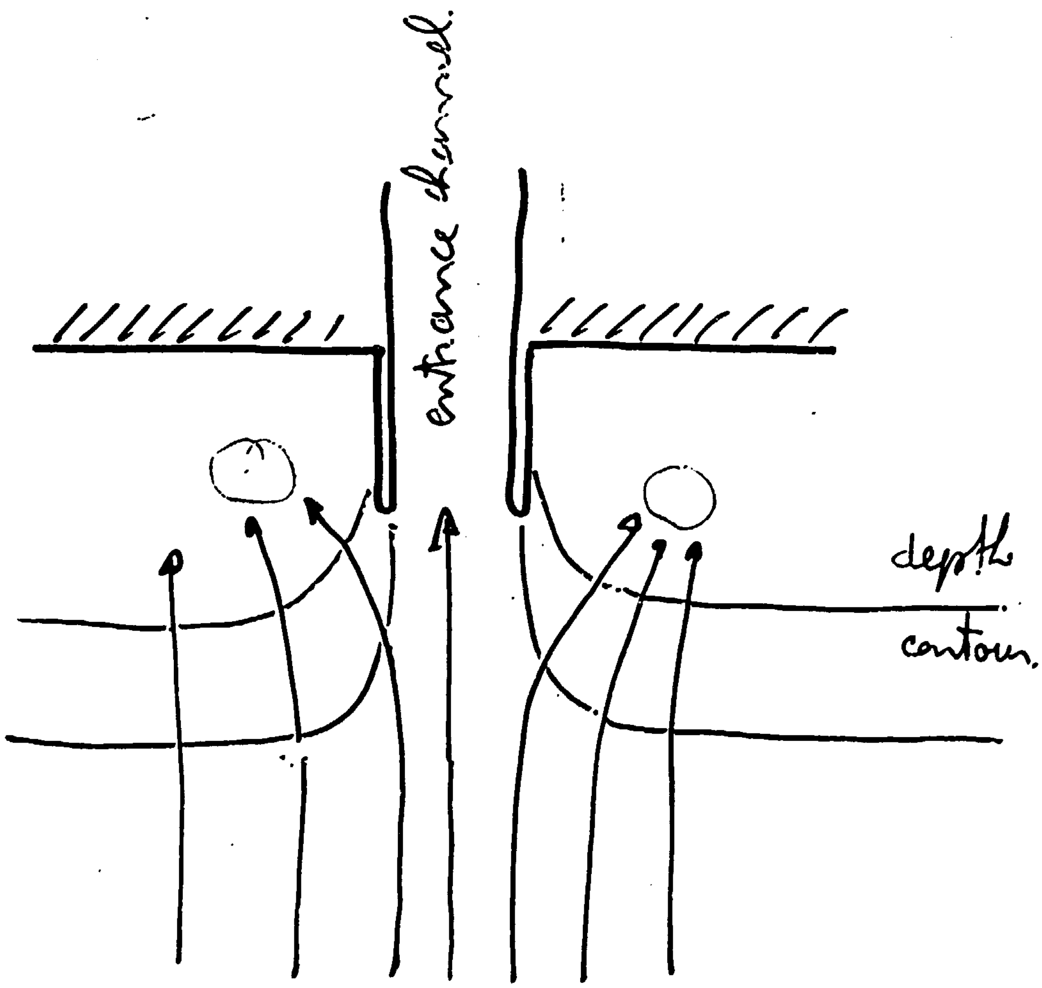
Diffraction

Wave energy does not flows actually only along rays if the wave height is not almost uniform in space.

Isolated breakwater



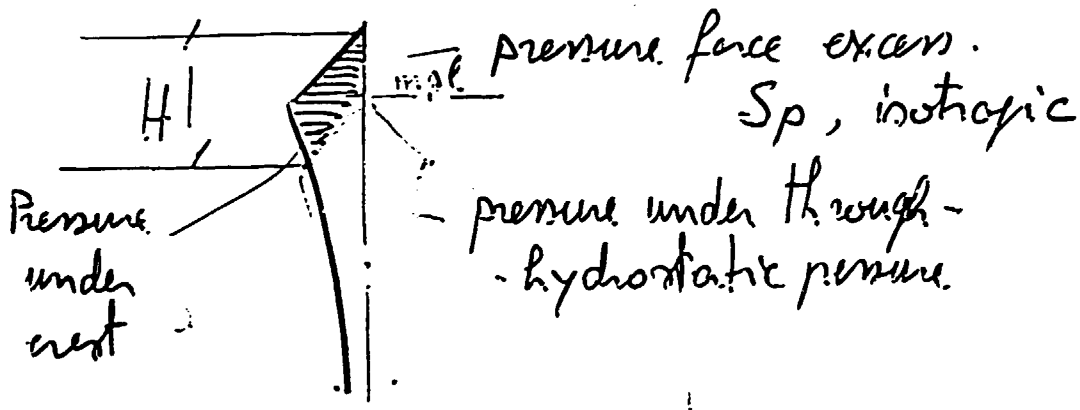

Head Land
depth contour
Wave energy concentration
wave rays

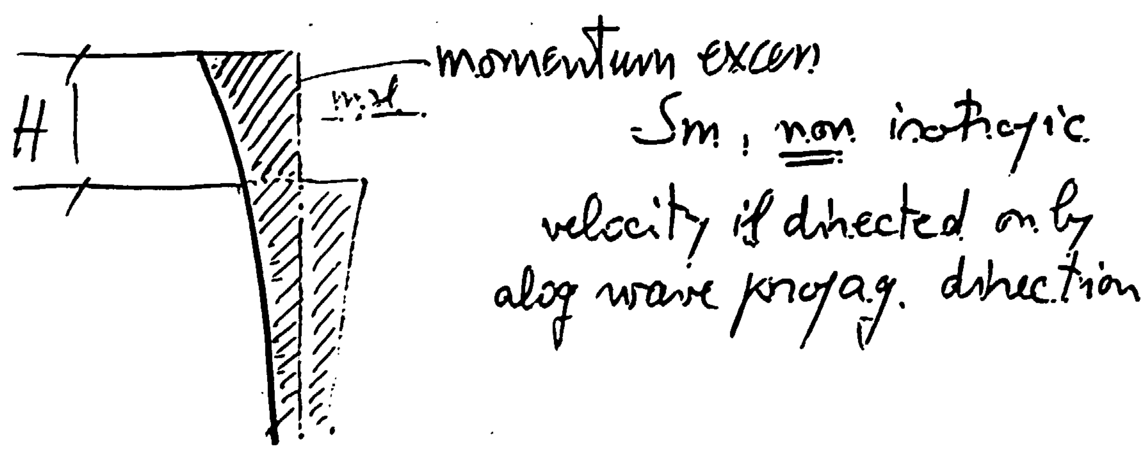

entrance channel
depth contour

Radiation stress - Mean wave forces

Waves determine pressure and velocity fluctuations in the water.
The net time average force due to these fluctuating quantities is not 0 as

p has the same phase of η and of u.



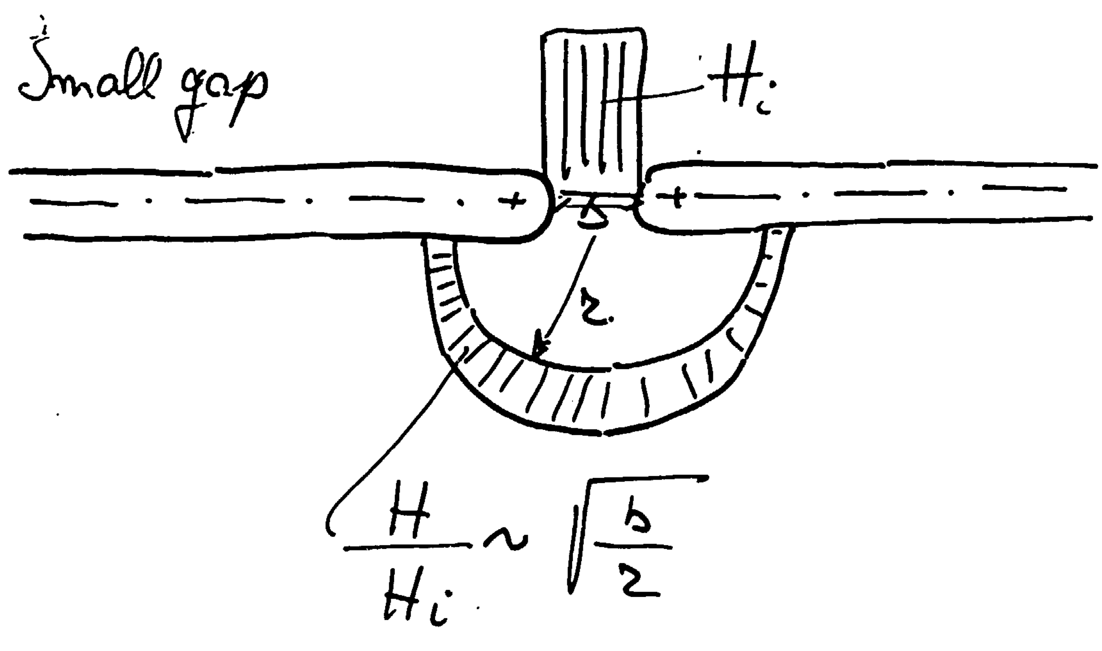


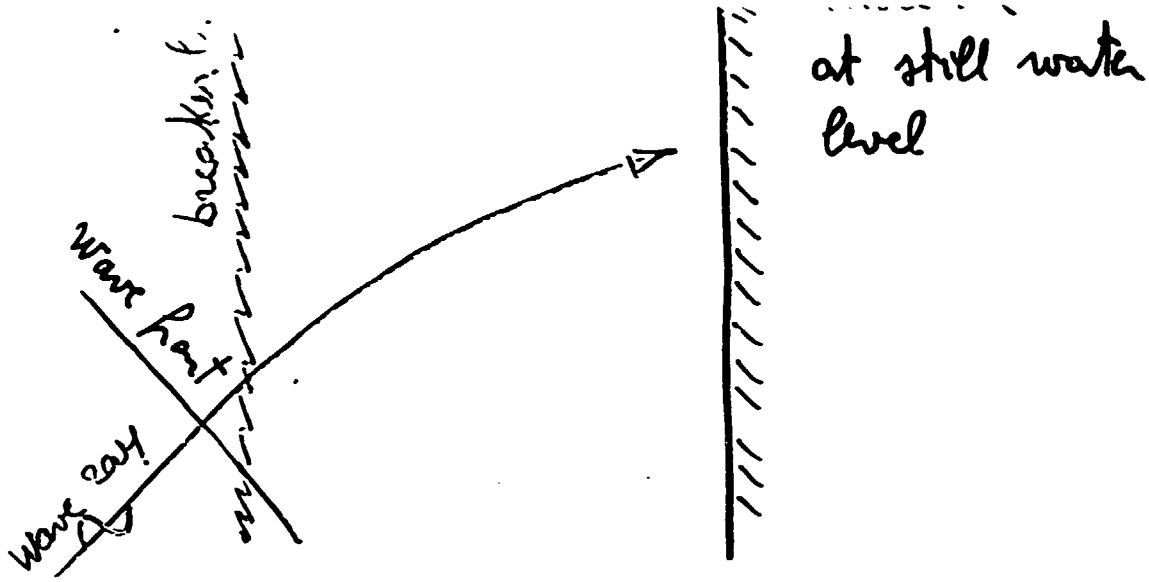
Huighens principle

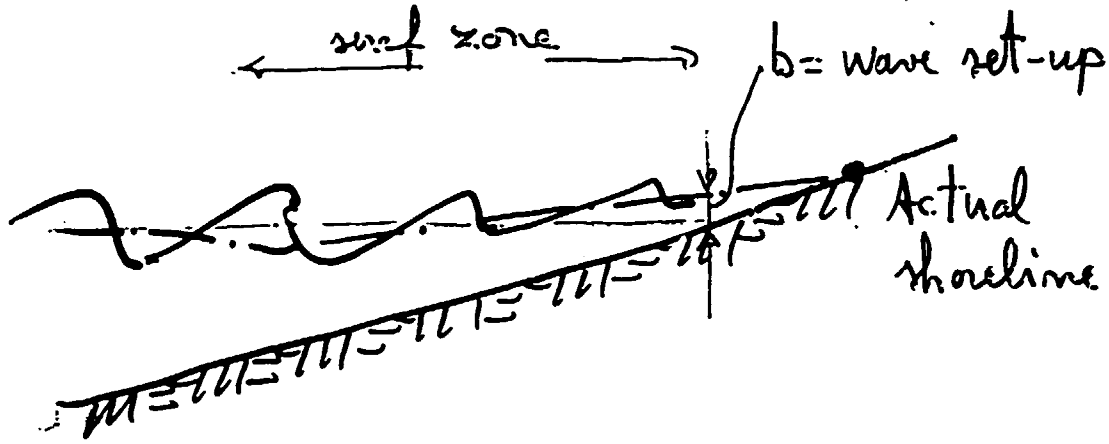
Every part of a wave front act as a point wave source irradiating the incoming wave energy according to

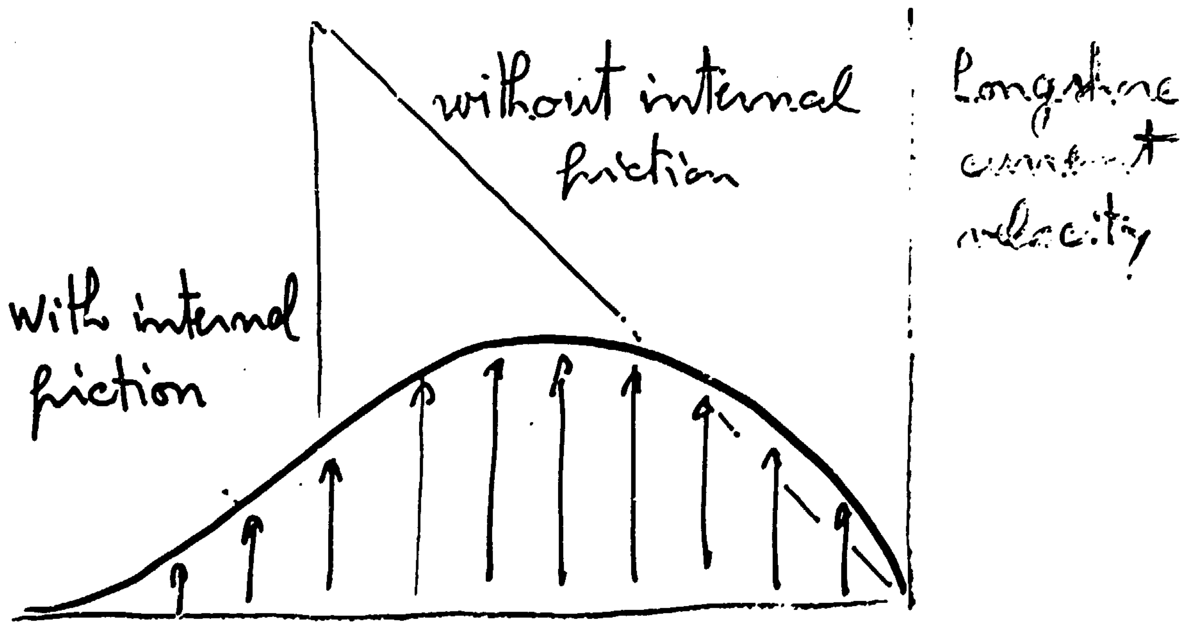
$$\frac{A(\varphi)}{A(0)} = \frac{1+\cos\varphi}{2}$$

A is the wave amplitude and φ is the angle between the incident wave and the current direction.




breaker l.
wave front
wave ray
at still water level


surf zone
b= wave set-up
Actual shoreline


without internal friction
with internal friction
Longshore current velocity

$$S_{\alpha\beta} = S_m e_\alpha e_\beta + S_p \delta_{\alpha\beta}$$

with e_α unit vector in the direction of wave propagation

$$S_m = E \frac{c_g}{c}$$

$$S_p = E\left(\frac{c_g}{c} - 1/2\right)$$

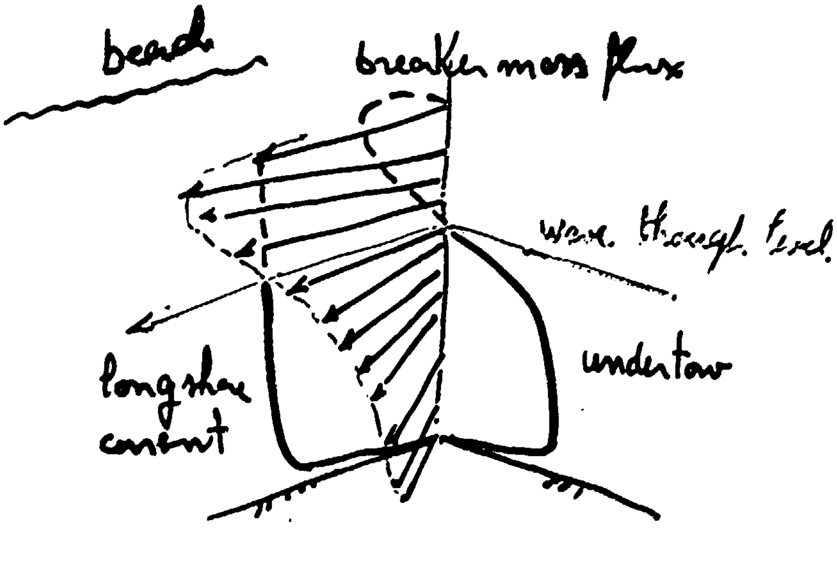
Longshore current

If waves approach the shore with an angle, the radiation stress produces a longshore force acting on the surf zone...

$$S_{xy} = E\, c_g \cos\alpha \,\frac{\sin\alpha}{c}$$

Longshore currents must be generated in order the bottom friction may balance the longshore thrust.

Momentum exchange is very active in the surf-zone as a consequence of
- turbulence
- crosshore circulation



Wave set-up

A wave approaching orthogonally the shore due to shoaling has varying length, height and radiation stress.

The variation in the net force the wave exert on a water column must be balanced by some slope of the mean water level.

Let b be the set-up: difference between the actual mean water level and the static level, i.e. offshore m.w.l.

Set-up is actually a set-down offshore the breaker line where dissipation is 0.

$$b = -\frac{1}{16}\frac{H^2}{d}\left(2\frac{c_g}{c} - 1\right)$$

$b \simeq -1$-10 cm even for large storm waves

In the breaker zone the dissipation cause a rapid decrease in E and increase in m.s.l up to $b \simeq 0.12\, H_b$ at the shoreline

($H = 0.6\, d$ is assumed to be valid in the surf zone)

Sediment Transport

Sediment transport in the littoral zone is due to the combination of wave orbital velocity stirring up the grains and of currents.

Currents may be due to waves (e.g longshore currents, undertow, rip currents) or to other causes as wind or tide.

For the special but frequent case of transport by longshore currents, waves are the only primary cause.
Many formulae are available.
The best known is the CERC formula

$$I_{ls} = 0.39 . P_{ls} = 0.39 \frac{\rho g}{16} H_{sb}^2 \, c_{gb} \sin 2\alpha_b$$

$$= 0.77 \, S_{xyb} \cdot c_b$$

I_{ls} = longshore sediment transport as submerged weight

The maximum longshore current velocity may be given by the modified Longuet-Higgins formula

$$V_{lo} = 20.7\, m \sqrt{g H_b} \sin 2\alpha_b$$

m = beach slope

H_b = breaker height

α_b = angle between breaker crests and shoreline

A longshore uniform situation appears to be often unstable.
Longshore current show oscillations.
In the case of a beach the longshore bar is cut by rip currents, where most part of the undertow is concentrated.

A formula accounting for a threshold (useful for gravel and cobbles) is (Van Hijum, Pilarczyk 1982)

$$Q/(g\,\Delta_{g_0}^2\,T_1) = 7.12\cdot10^{-4}\,Z(Z-8.3)\cdot\sin\alpha/\mathrm{tgh}(K_1 d)_{\text{foreshore}}$$

with $Z = H_{10}\cos^{1/2}\alpha/\Delta_{g_0}$

which for $Z\rightarrow\infty$ gives

$$Q = 0.0038\,H_1^2\left(\frac{gT_p}{2\pi}\right)\sin 2\alpha$$

Formulae including explicitly stirring up and transport are due to Bijker, Bailard, Van Rijn.

A similar formula is due to Kamphuis and accounts for sediment diameter and beach slope

$$Q = 6.4\,10^4 \; H_{sb}^2 \; T_p^{1.5} \; m_b^{0.75} \; D_{50}^{-0.25} \; \sin^{0.60}(2\alpha_b)$$

$m^3/year$

m_b = slope through the breaker zone d_b/y_b

y_b = distance of breaker from the shoreline

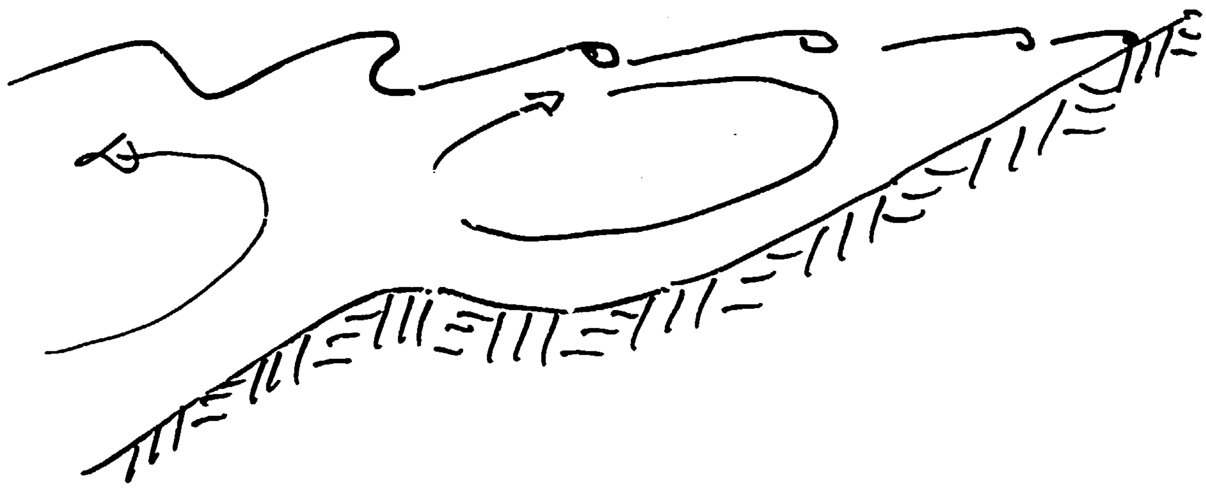
T_p = peak period

If a longshore gradient in wave height exists, the wave angle term should be changed to

$$\sin 2\alpha_b - K \frac{\cos\alpha_b}{m_b} \frac{\partial H_{sb}}{\partial x}$$

with $K = 1 \div 2$

Crosshore circulation



Essentially driven by the non uniform distribution over the depth of forces composing radiation stress.

Force are more intense near the free surface.

A formula accounting for a threshold (useful for gravel and cobbles) is (Van Hijum, Pilarczyk 1982)

$$Q/(g\Delta_{90}^2 T_1) = 7.12 \cdot 10^{-4} \, Z(Z - 8.3) \cdot \sin\alpha / tgh(K_1 d)_{foreshore}$$

with $Z = H_{10} \cos^{1/2}\alpha / \Delta_{90}$

which for $Z \to \infty$ gives

$$Q = 0.0038 \, H_1^2 \left(\frac{gT_p}{2\pi}\right) \sin 2\alpha$$

Formulae including explicitely stirring up and transport are due to Bijker, Bailard, Van Rijn.

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COASTAL PROCESSES AND COASTAL PROTECTION

COASTAL PROCESSES AND COASTAL PROTECTION

(By G.Liberatore, Università di Padova)

Outline

1. COASTAL PROCESSES

1.1 Generalities on hydraulic processes in the coastal zone

mainly due to wind (directly or indirectly)
(wind is directly responsible for the transport of sand on the dry beach and for the generation of waves, currents and water-level fluctuations).
most intense transport in the near-shore zone: small depths, waves break, wave energy is dissipated (and converted mainly into turbulence)

<u>Phenomena</u>

"wave setup" increase in the mean water level.
run-up and run-down:
During the up-rush, part of the water mass percolates and flows out again during the back-rush.
Breaking waves cause transport of water towards the beach, compensated by a seaward movement at a lower level, (the **"undertow"**).
In plan, offshore water transport also occurs due to **"rip currents"**. When waves approach the shore obliquely, also **longshore currents** are generated.
The orbital velocities due to the waves, the currents and in particular the turbulence of the water in the breaker zone cause sediments to be picked up from the bed and brought into suspension.
The currents in the coastal zone will transport the sediment,

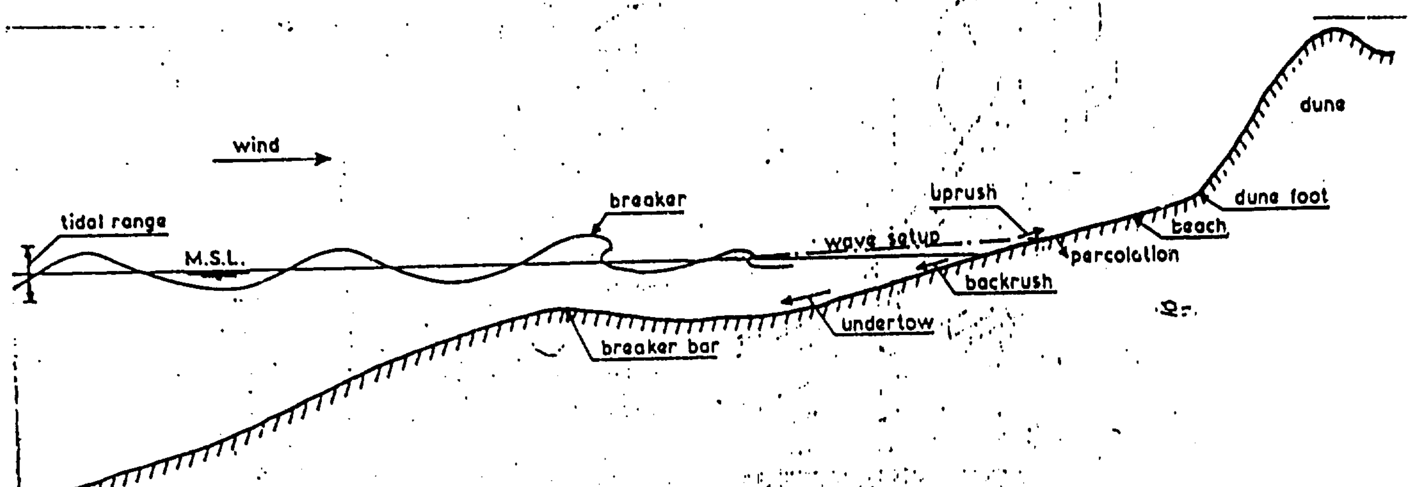
both in cross-shore and in along-shore direction.
The undertow will cause seaward transport of suspended sediment, while shoreward transport of suspended sediment occurs in the crest layers of the waves.
Shoreward transport also occurs near the bottom due to the asymmetry of the wave orbital motion.

Fig.1: sketch of hydraulic phenomena in the coastal zone

The longshore transport in the nearshore zone is governed mainly by the wave induced coastal current.
Because of their variability in height the waves break at different depths, causing a smooth form of profile of longshore currents.
This also applies for the cross-shore distribution of the longshore sediment transport

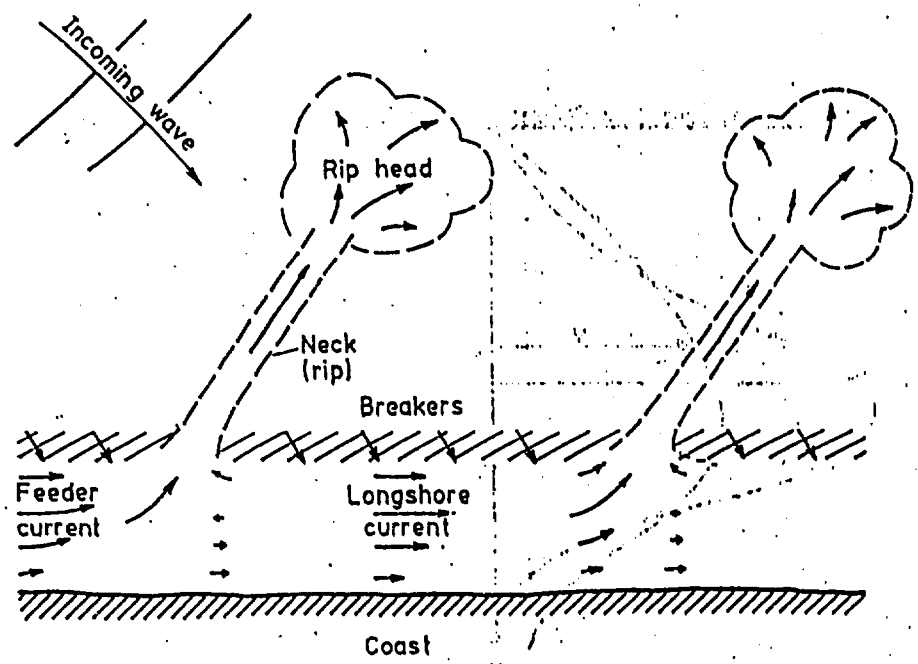
Fig.2: currents generated by breaking waves (plan)
Fig.3: profile of longshore currents and l. transport

shoreline changes : due to imbalance between sediment supply and transport capacity bathymetric will occur.
the imbalance may be natural (alternating processes, such as bar and spit formations) or due to human interference.
Examples of the latter: sediment trapping structures (groynes, harbour moles,etc., which cause the downdrift coast to erode).
- discriminate between short-term and long-term effects.
(short term fluctuations of the coastline may occur, because of the seasonal variations in the hydraulic conditions: they do not

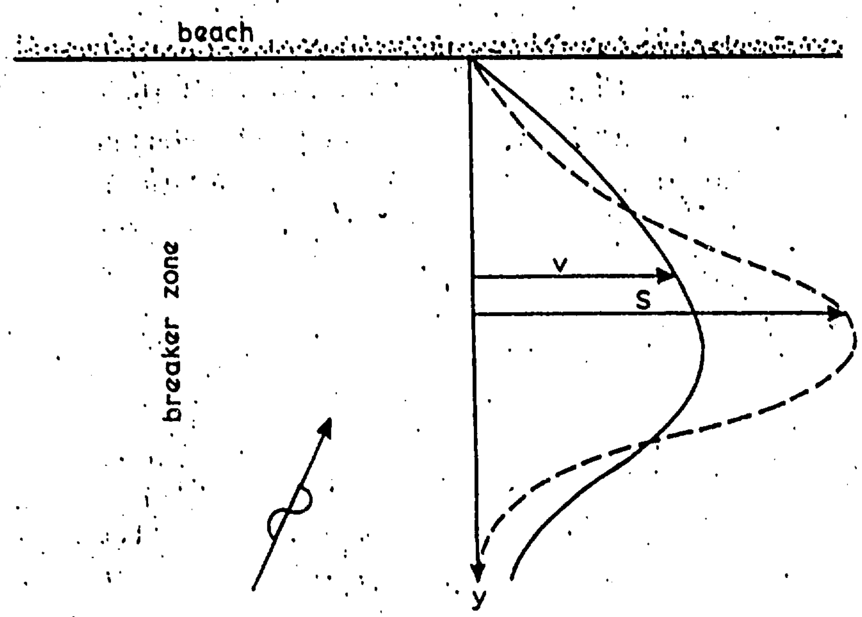


Schematic view of phenomena in coastal profile.

2.1



Currents generated by breaking waves (schematical).
Rip current consists of feeder current plus neck
(the rip current proper) plus rip head



Schematic view of longshore current (v) and longshore transport (S).

necessarily imply a long-term variability.

(Fig.4) Short-term and long-term coastline variations.

1.2 Sediments and transport phenomena

1.2.1 Sediments

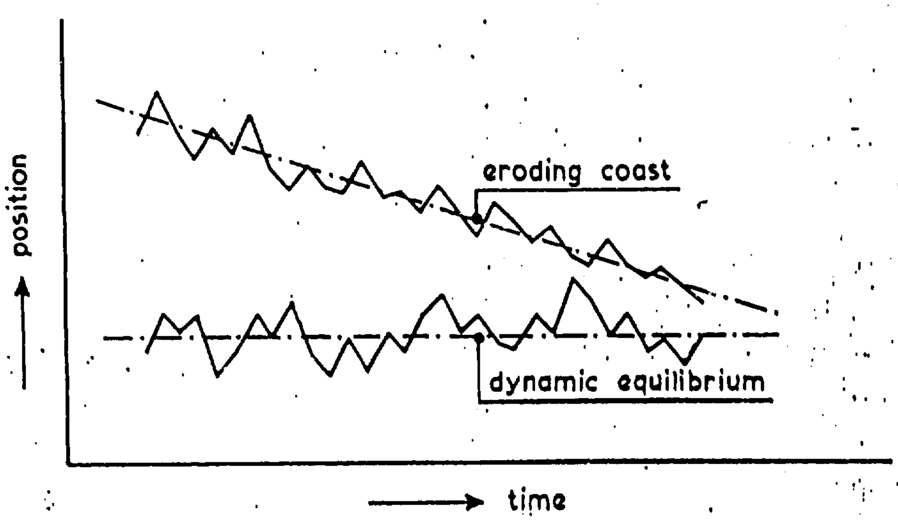
variable dimensions, from clay (a few μ in diameter) to gravel, cobble and boulder (several centimetres).
Most of beaches composed by sands with diameter D between 0.1 - 1 mm.

Classification

Wentworth classification is mainly used by geologists. This is based on phi-units, where

$$\phi = -\log_2 D$$

where D is in mm.
(The inverse relation is $D = 1/2^{\phi}$)
ϕ increases with decreasing diameters, thus allowing a better definition of smaller dimensions.
- metric classifications, such as the Unified Soil Classification (diameters in mm: easier physical appreciation).



Short-term and long-term coastline variations.

Classification of sands

	mm	ϕ
fine sand	0.06 - 0.25 mm	2 - 4
medium "	0.25 - 0.50	1 - 2
coarse "	0.50 - 2	-1 - +1

Size distribution

A given sand is represented by its size distribution. (the abscissas give the diameters or they logarithms, the ordinates the percentage (cumulative) in weight of material corresponding to the various diameters).

Synthetical parameters

A given size distribution may be characterised synthetically by a representative diameter (a medium or median diameter) and by the way the coarser and finer than the typical size are distributed . The median diameter D_{50} is usually used as the central value, whereas sometimes also the standard deviation and the skewness are calculated.

For most of engineering problems, D_{50} is by far the most important parameter.

Mean diameter $M_\phi = (\phi_{16} + \phi_{50} + \phi_{84})/3$

standard dev. $\sigma_\phi = (\phi_{84} - \phi_{16})/2$

asymmetry $\alpha_\phi = (M_\phi - M_{d\phi})/\sigma_\phi$

1.2.2 sediment transport

parallel and transverse sediment transport to the shoreline.

longshore transport (its gradients):

normally considered responsible for the long-term changes in the coastline,

cross-shore transport responsible for the short-term variations.

(presence of longshore transport: can be detected from the variations of shoreline and sea bed geometry near natural (river mouths, headlands) and artificial barriers (groins, harbour moles).

(short term effects: can be detected from changes of breaker bars, erosion of the dunes etc.)

-The net longshore transport per metre width is usually much larger than the net cross-shore transport.

the gross transports may be of the same order of magnitude.

Longshore transport

CERC empirical formula

:relates the longshore transport to longshore energy flux due to breaking waves

$$S=A\ H_0^2 c_0 K_{rb}^2 \text{ sen } \alpha_b \cos \alpha_b$$

where:
[S] = longshore transport due to breaking waves (m^3/s)
A = constant
H_0 = deepwater wave height
C_0 = deepwater wave celerity
K_{rb} = refraction coefficient at the breaker line
α_b = breaker angle

A=~0.025 (assuming H_0= significant wave height)

Uncertainties related to:

- inaccuracies in the data (for waves and for longshore transport, on which the model is based);
- does not account for differences in grain size;
- valid only for long and straight beaches
- does not account for currents which are not generated by breaking waves (such as tidal currents)

Bijker formula:

calculates longshore transport from coastal currents (which may be evaluated theoretically by radiation stress concepts, using sediment transport formulas (for suspended and bottom load) Effects of other currents (tidal currents) may be included.

Cross-shore transport

Bakker (1968) has proposed a model for the computation of the coastal evolution. He schematised the coast with to lines.

Recent sediment transport theories

two kinds of models:

1) models which describe wave induced water motion and from this the sediment motion via formulations of the interaction between water and sand;

2) models including formulations of energy dissipation due to breaking waves and relate this dissipated energy to sediment movement, as much as possible through water movement.

1.3 Coastal morphology

General aspects

- morphological evolutions are a direct consequence of changes in sediment transport

when the sediment transport diminishes the bed will rise, and conversely an increase in sediment transport will cause erosion

short term and long term evolutions, though a clear distinction between these two types of evolution as far as time scale is concerned cannot be made:

- "a number of years" in the case of long term evolution;
- for short term evolution, the time scale may be quite variable (a single storm, but also yearly variations in the wave climate).

for decisions regarding beach protection measures, long term developments are important, although the decision may be actuated by short term developments

the cross-shore transport, and thus the variations in the coastal profile, is mainly responsible for the short-term fluctuations in the coastline, while the long-term evolution of the coastline is mainly governed by the gradients of longshore transport

1.3.1 Coastal profiles

form of the coastal profile and its variations are mainly governed by the cross-shore transport

related to waves:

wave conditions vary→

form of the coastal profile varies

(particularly in the nearshore zone, where the transports are largest).

- type and shape of the profile

Type of coastal profile (Fig. 5)

a distinction is common between bar profiles and step profiles

bar profiles: usually identified with eroded profiles; also called winter or storm profiles

step profiles: summer, ordinary or berm profiles

this means that bar profiles can be found during or shortly after storms with offshore transport, whereas step profiles are formed during periods with moderate wave conditions and onshore transport.

formation of bar or step profile is usually related to wave attacks and beach material

e.g.

Dean's criterion (1973):

wave steepness separating bar and step profiles depends on parameter

$H_0 / (V_f T)$

where V_f is the fall velocity of the median grain size D_{50}.

According to Dean, C=0.85;

SPM: C=1 (C < 1: accretion; C>1 erosion)

Other criteria: Sunamura and Horikawa (1974) (including slope of the profiles)

Fig.5 **Definition of bar and step profiles**

Shape of coastal profile

various attempts have been made to describe the shape of the equilibrium profile

Bruun (1954)

$$h = Ay^{2/3}$$

where:

h= water depth
y= distance from the shoreline
A= factor

Dean (1977)

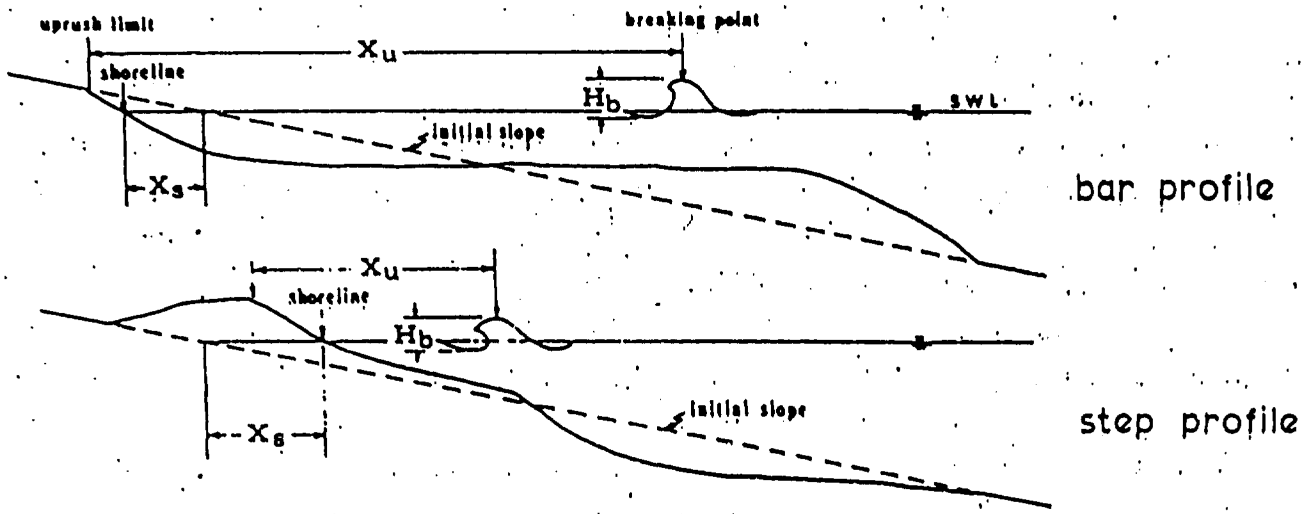
$$h = Ay^{m}$$

where:

A= shape factor, depending on the stability characteristics of the bed material
m = value of exponent

Substitution of Moore's result (1982) $A \sim D^{1/3}$ gives, for m=0.67:

$$h = B\, y^{2/3}\, D^{1/3}$$



Definition of bar and step profiles (SUNAMURA and HORIKAWA, 1974).

where B is an unknown factor which is likely to be dependent on several variables (wave climate, water level variations, coastal currents, etc.)

Vellinga (1984) gives a general expression for the erosion profile in the nearshore zone.

Remarks

-in nature the form of a cp is determined by the average wave climate and by other factors, (water level oscillations, surf-beats, tidal currents etc.); the application of steady conditions is too a drastic schematization to obtain profiles similar to those in nature

- in nature a coastal profile is continuously reshaped by varying hydraulic conditions and an equilibrium profile will never be obtained

: therefore it is difficult or even impossible to find accurate and reliable relations between the geometric features and wave conditions

only rather rough descriptions of the average yearly profile are possible, such as those by Bruun and by Dean

1.3.2 **Long-term morphological developments**

For the planning and design of coastal works, (harbours, groynes,...) it is important to know the effects of these works on the behaviour of the coast.

usually possible to obtain an insight into these effects on the basis of a study of the coastal processes in the area,

- for quantification of the effects it is possible to

- carry out experiments on small scale models
- apply mathematical modelling.

<u>One-line coastal models</u>

the simplest model: the coast is schematised into a single line we assume that the coastal profile does no change, so the profile translates horizontally over its full active height as a result of accretion or erosion

Fig. 6: schematization of one-line model

The equation of continuity can be derived from the figure:

$$\frac{\delta S_x}{\delta x} + h\frac{\delta y}{\delta t} = 0 \qquad (1)$$

where S_x = longshore transport
h = height of schematised profile
x = axis along the original coastline
y = axis perpendicular to the original coastline
t = time

The equation of the motion can be written as :

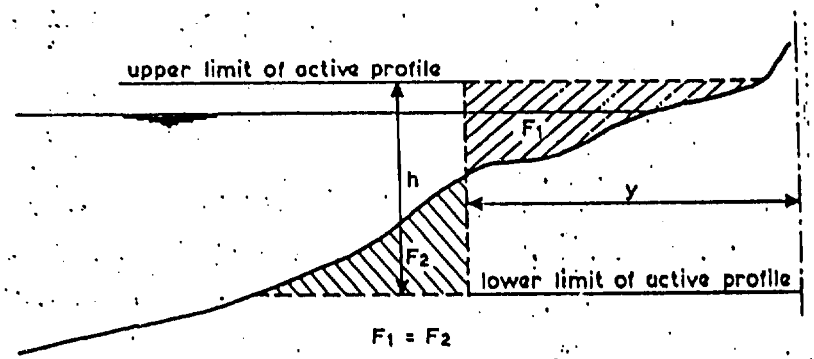
$$S_x = S_0 - s\frac{\delta y}{\delta x} \qquad (2)$$

where:

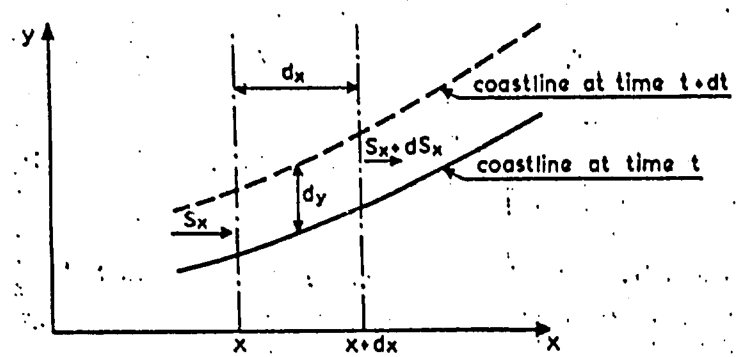
S_0 = longshore transport for the coast parallel to the x-axis;
s = variation of longshore transport per radian coastline rotation

By combining Eq. 1) and 2) and assuming S_0 and s constants, we obtain Pelnard- Considere equation:

$$\frac{\delta y}{\delta t} = \frac{s}{h}\frac{\delta^2 y}{\delta x^2} \qquad (3)$$



Profile schematization for one-line model.



Plan view for one-line model.

(analytical solutions have been obtained).

For the computation of the coastline evolution the values of S_0, s, ϕ, and h should be known.

S_0: can be computed using the CERC formula;
(in order to obtain the resulting annual transport, the contributions of the various wave conditions should be added, taking into account the frequencies of occurrence; results of the computations may be inaccurate, and, when possible, they should be checked by volumetric measurements of erosion volumes and accretion).

Two-line coastal models

also on-offshore transport may be simulated in a simplified way using two lines

Two-dimensional coastal models

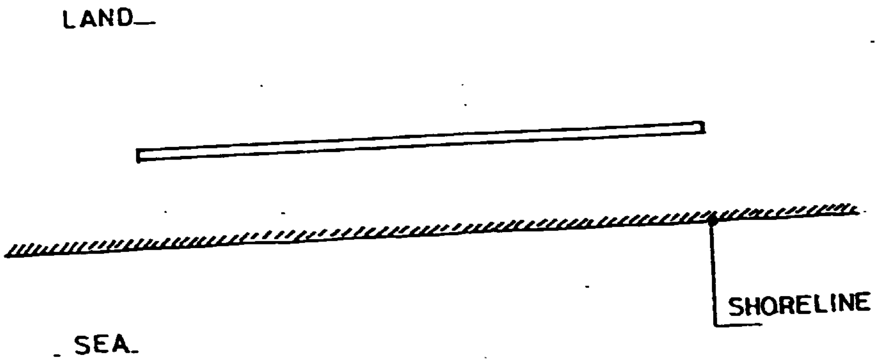
at present various researcher are attempting to develop two-dimensional numerical models of the coastal morphology, such as the model by Boer et al.(1984)

the model is a system of mathematical models for computing wave propagation, currents, sediment transport and resulting bottom changes

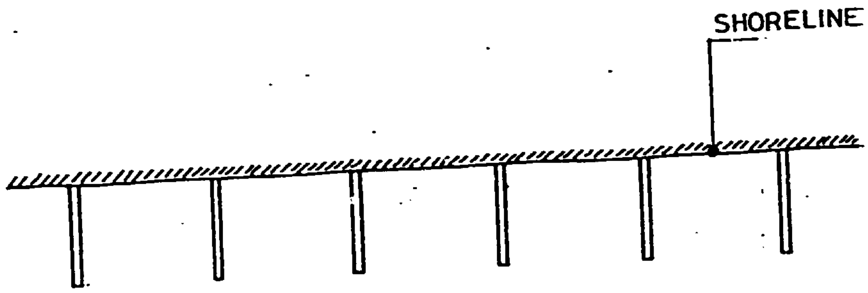
2. COASTAL PROTECTION

rigid protections	2.1 Seawalls (Longshore Parallel Protections) 2.2 Groins (Cross-shore protections) 2.3 Detached breakwaters (Longshore Detached Protecti
soft protections	2.4 Artificial'Beach Nourishments

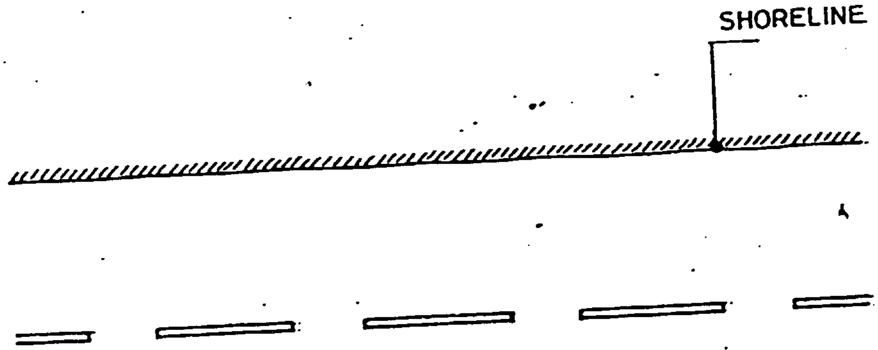
Fig.7 : schemes of rigid protections



SEA WALLS



GROINS



DETACHED BREAKWATERS

2.1 Longshore Parallel Protections

function:

they are built

- either to prevent the transverse transport of beach material from the beach toward deepwater
- or simply to protect the hinterland from flooding from the sea.

(seawalls, dikes or beach revetments: seawalls are massive structures; dikes are protected slopes)

design parameters: length, height and shape of the structure

A very important aspect of seawall design is to predict the maximum depth of erosion at the seaside toe of the structure.

Due to the much higher reflection coefficient of seawalls compared with sandy beaches, more turbulence in front of the seawall occurs, causing erosion at the toe of the structure.

The slope of the seawall has been found to be an important parameter determining the toe erosion depth; generally the erosion depth in front of a vertical wall was found to be less than in front of a sloping wall.

limitations: they only afford protection to the zone to be protected and none to the adjacent areas.

When built on a receding shoreline, the recession will continue and may be accelerated on adjacent shores.

Any tendency toward loss of beach material in front of the structure may be intensified. Where it is desired to maintain a beach in the vicinity of the structure, complementary works may be necessary.

It is generally not recommended to make use of this method to protect the shore.

2.2 Groins (cross-shore protections)

function: they interrupt the longshore transport of sediments, causing settlement at the updrift side of the groin

groins do little to prevent the transverse transport of sediments in the cross-shore direction; for this, other measures should be taken.

usually systems of groins:

Fig.8 : geometry of a groin systems

Design parameters for a system of groins:

l = length (distance between shoreline and tip of the groin)

s = spacing (distance?)

h = height

length **l** depends on the fraction of littoral drift to be interrupted; varies, d=2-3 m

spacing **s** generally varies between (1.5-4) l, more frequently (2-3) l, with wider spacing for beaches subject to nearly parallel approaching wave crests.

height **h** :

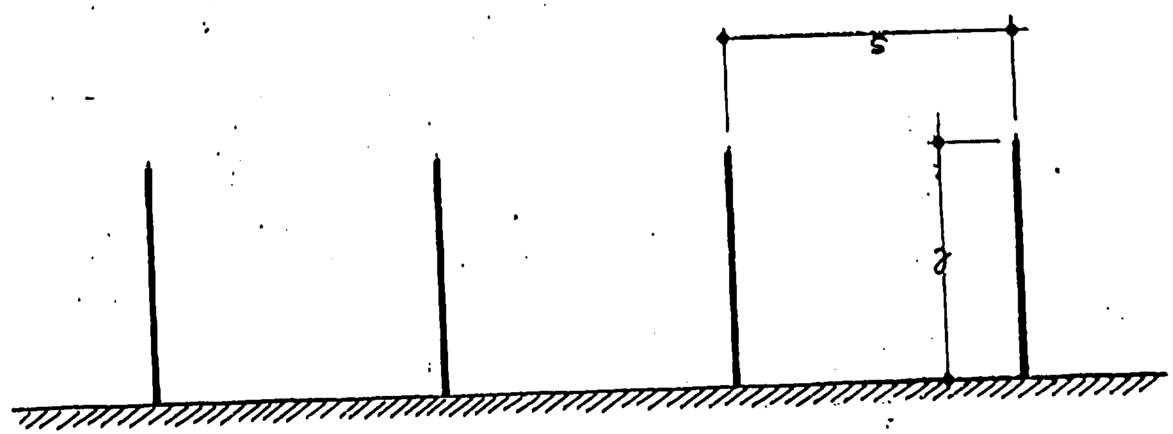
in the offshore (usually horizontal) section the minimum compatible with economy and safety; in Italy (low tides) heights between 1-1.5 m are usually adopted

in the (horizontal) shore section: the minimum height is that of the berm (max high water+uprush)

in the intermediate section: about parallel to the slope of the foreshore

alignment: usually normal to the beach

planimetric shape better simple straight groins;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also curved, hooked, T- and L- heads

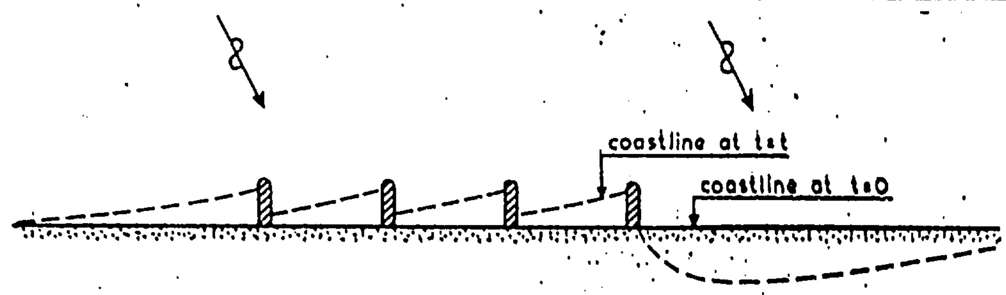
Permeable groins : pile rows, causing reduction of littoral drift

Order of construction: preferably, start from the most downdrift groin (unless cells are filled artificially)

Limitations: the area protected by a groin system will usually accrete; however, downdrift of the last groin increased erosion will occur: the groins simply shift the erosion problems

they may be useful in particular cases (when erosion of downdrift beaches is not a problem)

Fig.9: Effect of a groin system on a beach



Effect of groyne field on coastline.

2.3 **Detached breakwaters** (Longshore Detached Protections)

2.3.1 EMERGING BREAKWATERS

<u>Definition</u>: Detached breakwaters of the emerging type consist of single segments or, more frequently, of series of segments separated by gaps.

<u>Function</u> :

-they act on incoming waves;

waves and associated currents decrease in the protected area; sediments settle

-they may influence both long-shore and on-offshore transport of sediments

- effective solution (for areas of small tidal oscillations) for beaches to be protected:

<u>breakwater geometry</u> (Fig.10: scheme)

main parameters are:

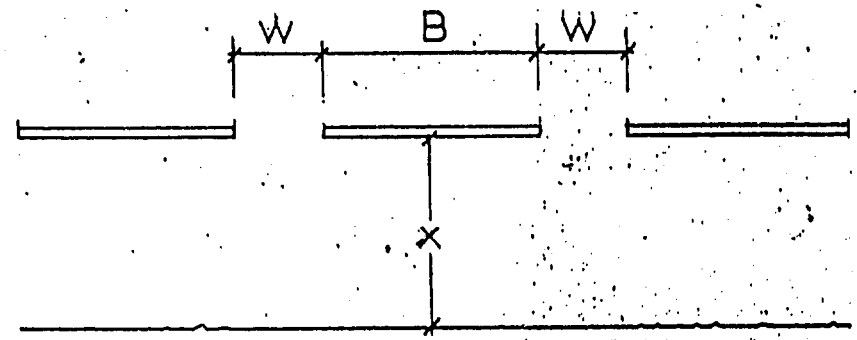
- breakwater length (B);
- gap width between breakwaters (W);
- distance of breakwater(s) from the original shoreline (X).

(In Italy typical lengths are about 100 m or below, with gaps of 25-40 m).

formation of tombolos occurs for $X/B < 1$ and formation of salients for $X/B > 1$, whereas breakwaters are considered ineffective for $X/B > 2$

<u>Advantages</u>

detached breakwaters are in many cases an efficient method of shore protection.



Detached breakwater

-They offer immediate protection to the beach to be defended (even before the trapping effect of sediments has widened the beach).

-advantages
- compared to groins (which have little influence on wave attack before accretion of the beach has occurred)

- compared to seawalls (which protect the land behind, but do not help in accreting the beach.

drawbacks

- downdrift shift of erosion phenomena (necessity of protecting the downdrift beaches).

- environmental problems:
- degradation of the quality of sand and water in the protected areas (particularly in the case of tombolos)

- irregularity of the emerged beach and depth contours, (dangerous particularly for swimmers);

- degradation of the visual aspect of the beach

- also on protected beaches results in some cases unsatisfactory, (insufficient sediment transport, subsidence,...)

Fig.11: typical section of an emerging breakwater

Example :

very long uninterrupted sequences of detached breakwaters (up to 20 km long between Rimini and Cesenatico)

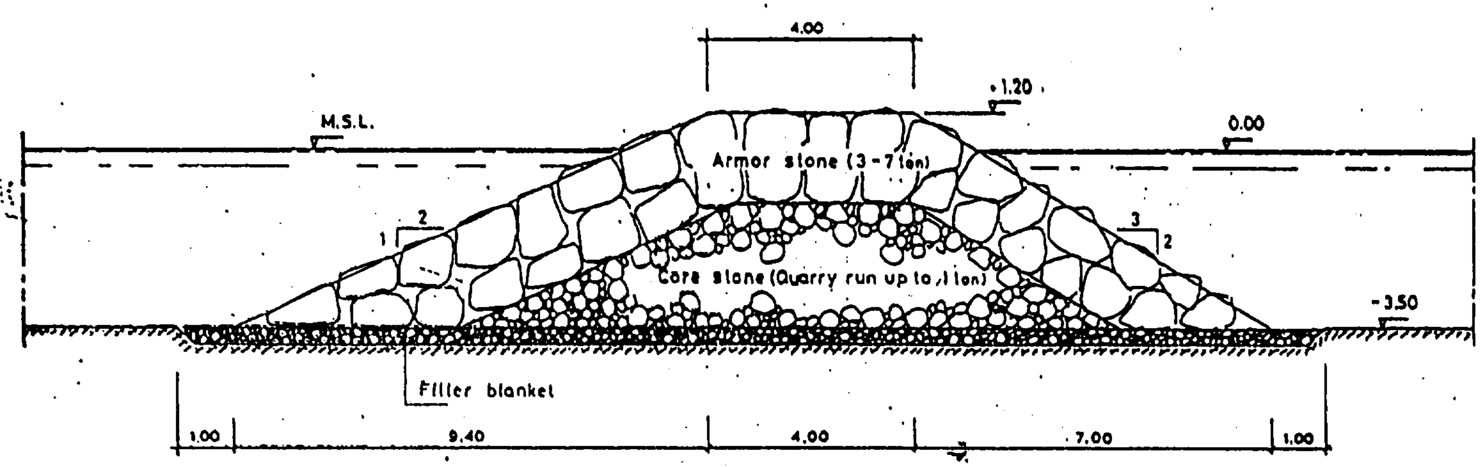
Fig.12: Detached breakwaters built between Rimini and Cesenatico (Italy)

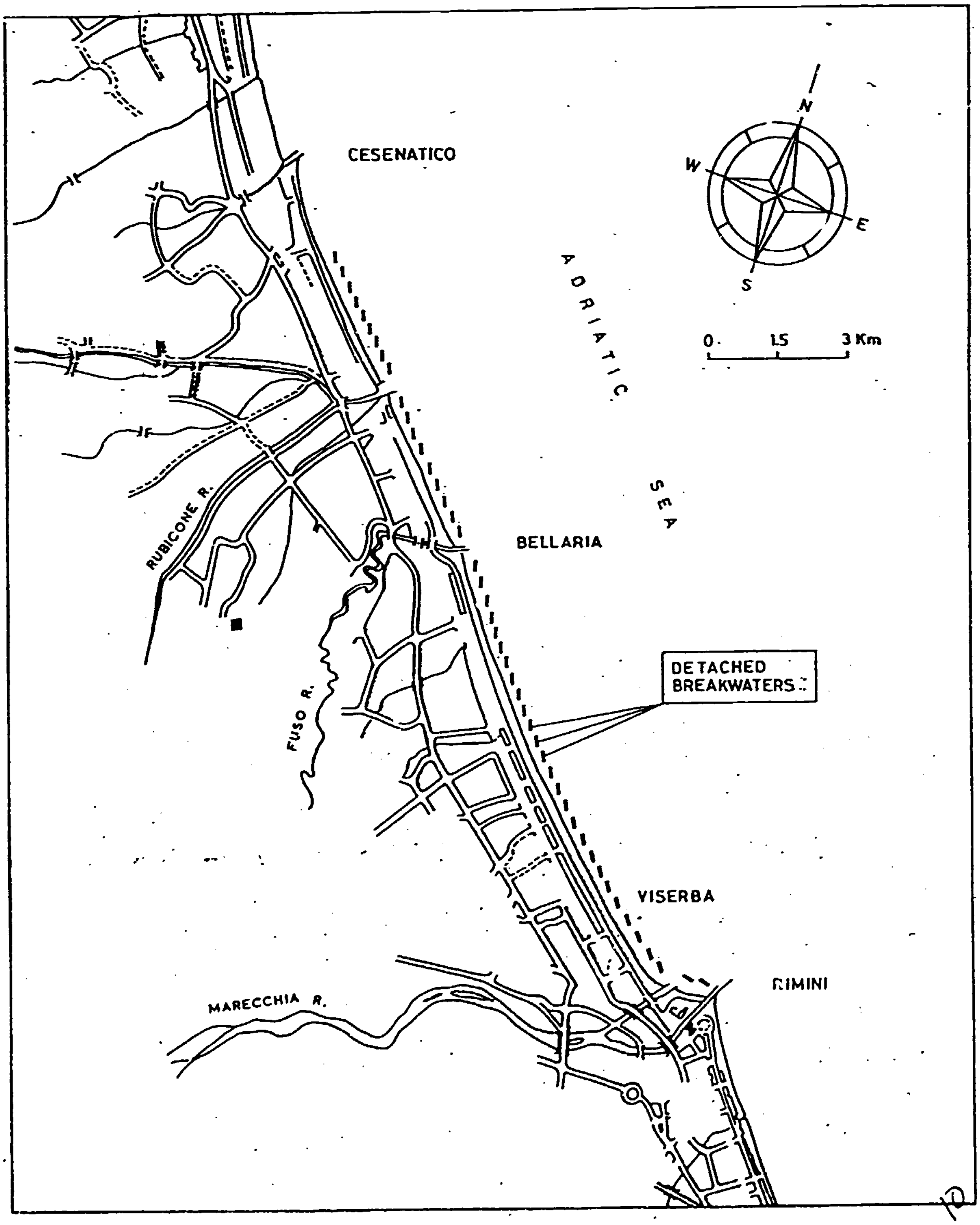
2.3.2. SUBMERGED BREAKWATERS

Description

long, continuous structures parallel to the shoreline

(gaps are not necessary for water exchange; they may be provided


4.00
+1.20
M.S.L.
0.00
Armor stone (3-7 ton)
1
2
3
2
Core stone (Quarry run up to 1 ton)
-3.50
Filter blanket
1.00
9.40
4.00
7.00
1.00



CESENATICO
N
W
E
S
ADRIATIC
SEA
0
1.5
3 Km
BELLARIA
RUBICONE R.
FUSO R.
DETACHED
BREAKWATERS
VISERBA
RIMINI
MARECCHIA R.

for other reasons, e.g., to allow the passage of boats).

Advantages

- they are invisible;
- influence on waves is more selective (larger waves being subject to stronger reduction; wave-induced water circulation is less affected during minor and moderate wave attacks);
- a softer and more regular impact on the protected and downdrift beaches

design parameters

most important parameters :

-submergence of the crest h_t

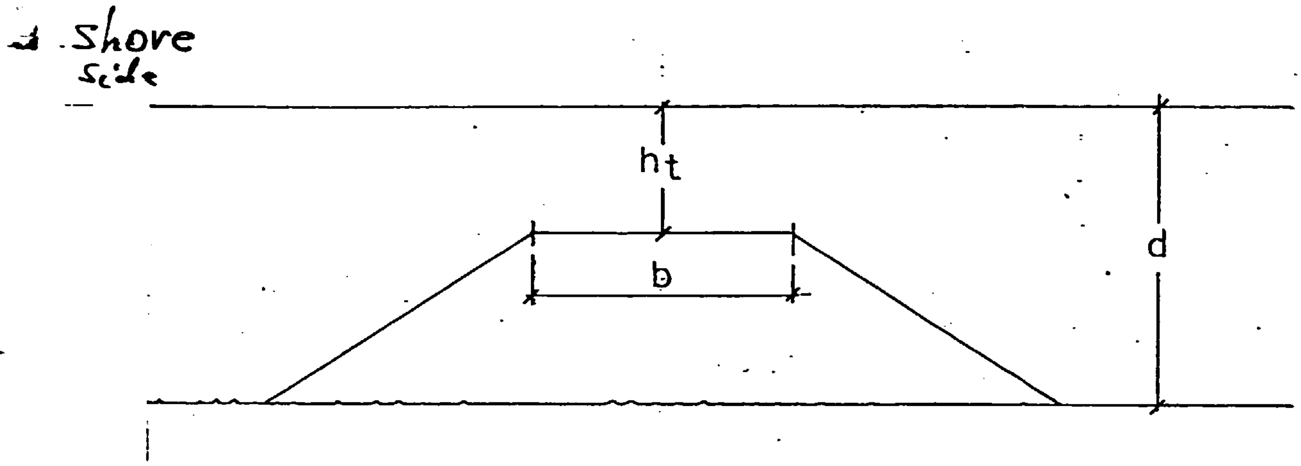
-width b

Fig.13. Scheme of a submerged barrier

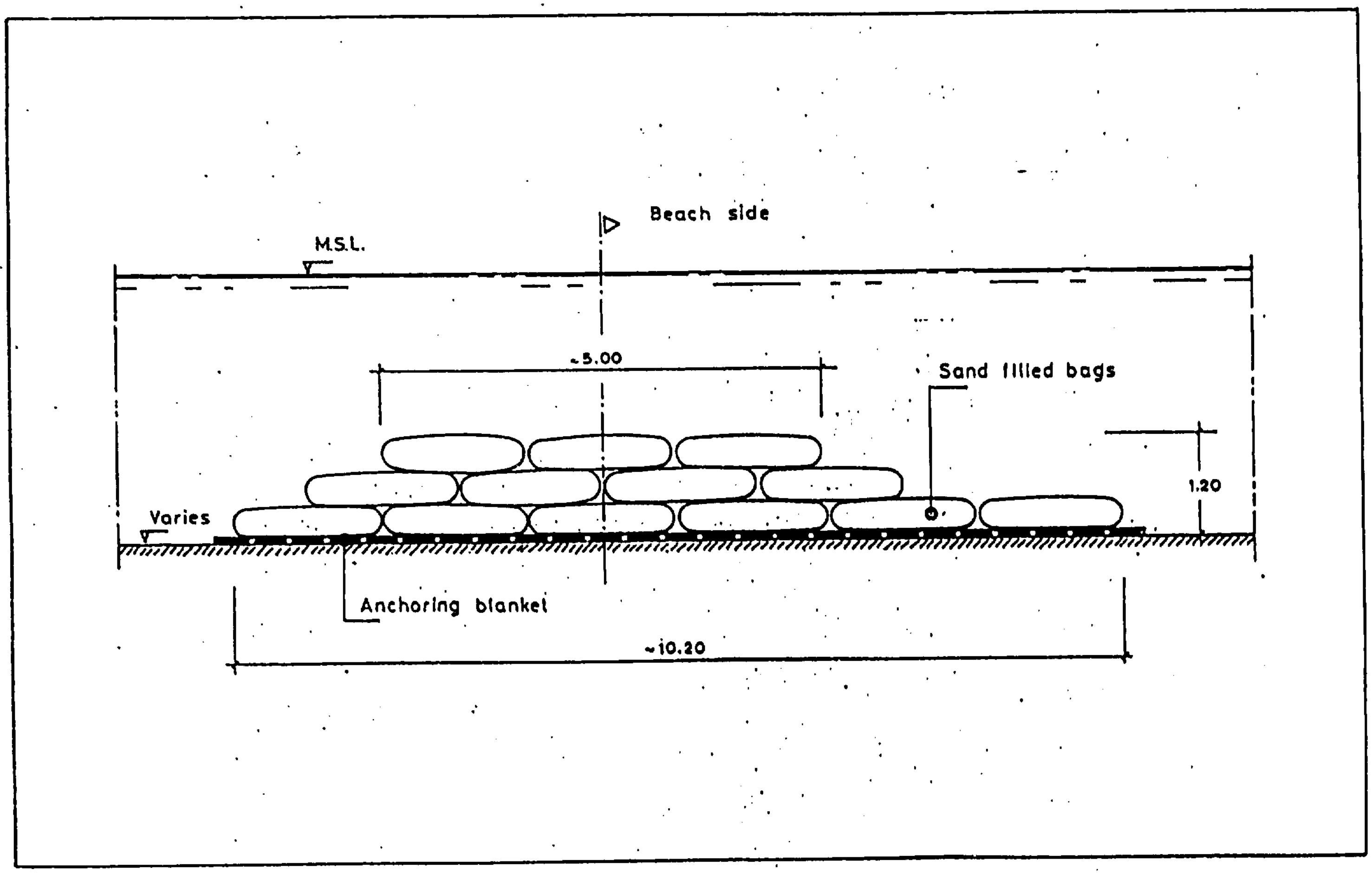
Fig.14. Scheme of a submerged barrier of sand-filled textile bags

problems

- still little is known about their effectiveness as shore-protection structures
- scouring problems, particularly at the shore-side foot for low barriers



Submerged barrier


Beach side
M.S.L.
~5.00
Sand filled bags
1.20
Varies
Anchoring blanket
~10.20

2.4 ARTIFICIAL BEACH NOURISHMENT

probably the simplest and most dependable means of maintaining an eroding beach: supply sand from other sources

Design parameters

1- size of material

the grain size should be equal to o larger than the native sand (to avoid a quick erosion of the new material)

the difference should not be too large (unacceptable steep slopes)

2 - amount of material

closely related to the amount of sediment transport

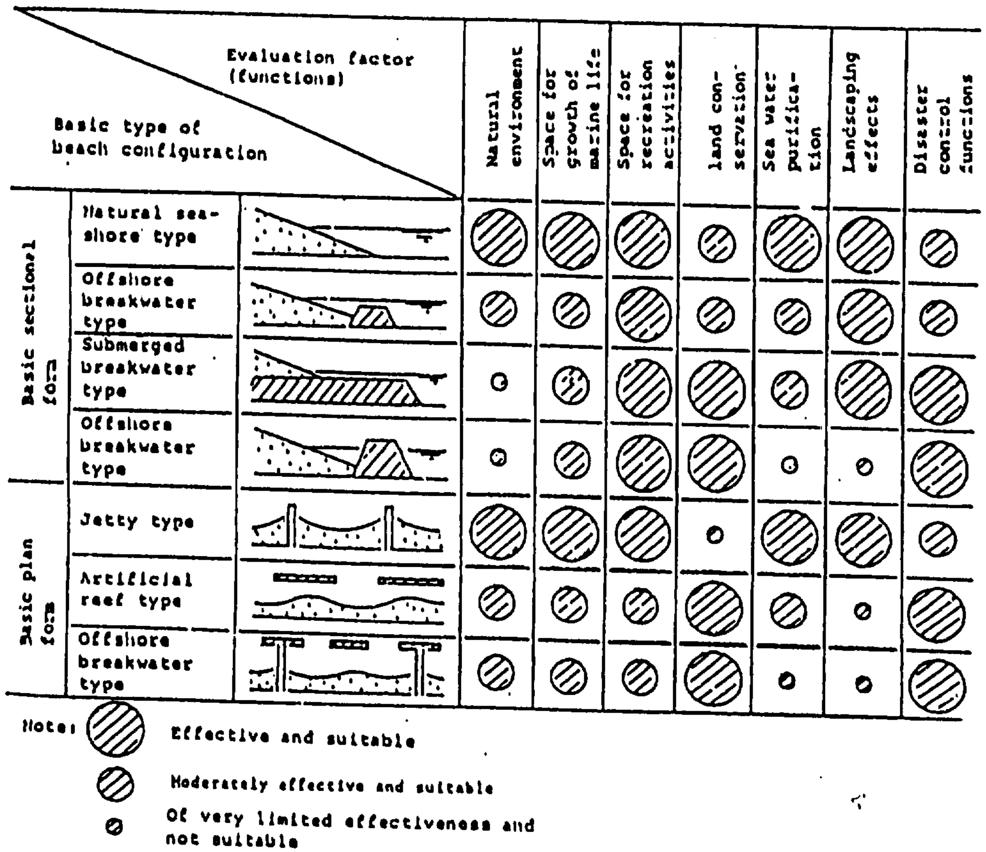
longshore transport rate and the nourishment interval + the sand volume needed for the desired stabilised beach profile should determine the total volume

3- sources of beach fill material

the sand can be obtained

- offshore (far from or near to the beach)
- on land

in sheltered waters



Selection of beach protection measures (KOBAYASHI et al., 1985).

Selection of beach protection measures

Fig.15 gives an example of a selection procedure, taken from Kobayashi et al. (valid for a particular problem at Yokohama).
In other cases different evaluations will be done.
zero option: in many cases, the easiest and cheapest method to avoid problems is to do nothing and leave the area which has problems
unfortunately, very often this is not acceptable to people for a number of reasons

Concluding remarks

- better, whenever possible, artificial nourishment
- rigid structures to be used very carefully;
may be very dangerous for the coast, and the problems they cause are often greater than their advantages
- if they are used, preferable to fill the protected beach in order to minimise erosion of downdrift coast

Giampietro - Puppi

Tecnomare

Sea level variations

SEA LEVEL VARIATIONS (PROF. PUPPI)

In the Hystory of the earth, sea level has changed on all temporal scales due to various causes.

<u>Local phenomena</u> (short temporal scales)

a) Tides and winds
b) Subsidence or uplift of coastal areas
c) Erosion and sand supply at the coast and other human activities
d) Regional tectonic movements

<u>Global phenomena</u> (long temporal scales) (Eustatic sea-level changes) due to phenomena like:

i) Climatic variations
ii) Plate tectonics

We are going to discussing the consequences of climatic variations because there is today a great interest not only among scientists but also among politicians because for a possible increase of eustatic sea level can threaten coastal lowland human settlements.

- What knowledge do we have of the relationship between climatic changes and sea level variations?

- Most impressive example is related to the last glaciation on earth, initiated about 120.000 year ago: sea level was 120 m. below today level, mean earth's temperature > 5° less than today, and latitudinal gradient of temperature much greater than today.

- For our purpose it is crucial to discuss the so called "Greenhouse effect" due to the presence in the atmosphere of the so called "Greenhouse gases" like water vapour, CO_2, CH_4, N_2O, CFC etc. in order of importance for the effect.

- On short time scales, like the ones we are interested (decennia or a century) for climatic changes, is just the variation of the "Greenhouse effect" the possible cause; and more precisely the increase in the importance of that effect as a due to continuous accumulation of "Greenhouse gases" as a consequence at human activities (example of CO_2).

- Which are the basis for connecting:
  Increase of Greenhouse gas in the atmosphere;
  Increase of mean earth's temperature;
  Increase of eustatic sea level

- The <u>observation</u> of a trend in the global mean temperature in the last century.

- The <u>theoretical results</u> from climatological models of the consequences of an increasing content of "Greenhouse gases" in the atmosphere".

- Which are the physical processes connecting the increase or decrease of earth's temperature with the increase or decrease of sea level?
  <u>On the large scale</u> (glaciations and deglaciations) are:
    Accumulation of snow and ice on the continents at high latitude and subsequent melting
  <u>On the small scale</u> (the case of increase):
    Thermal expansion of the oceans.
    Water flow in the oceans by terrestrial sources.
    Partial melting of sea ice and polar cups.

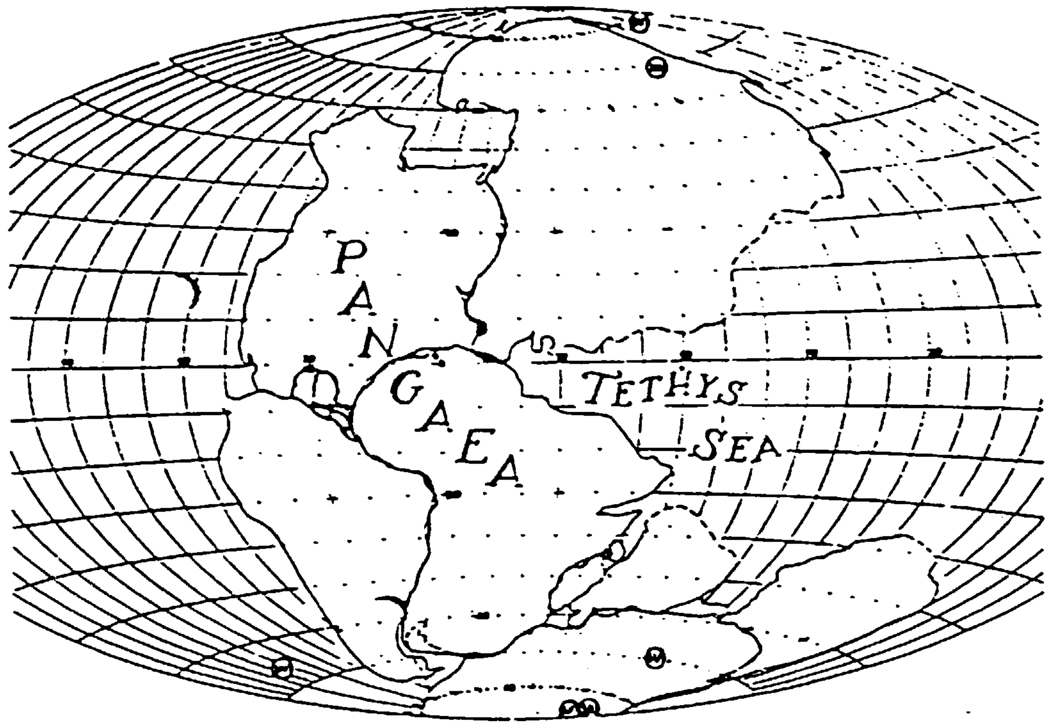


Fig. 2. Reconstruction of the continents into the universal landmass of Pangaea as of the end of the Permian, 225 m.y. ago. See text for full explanation.

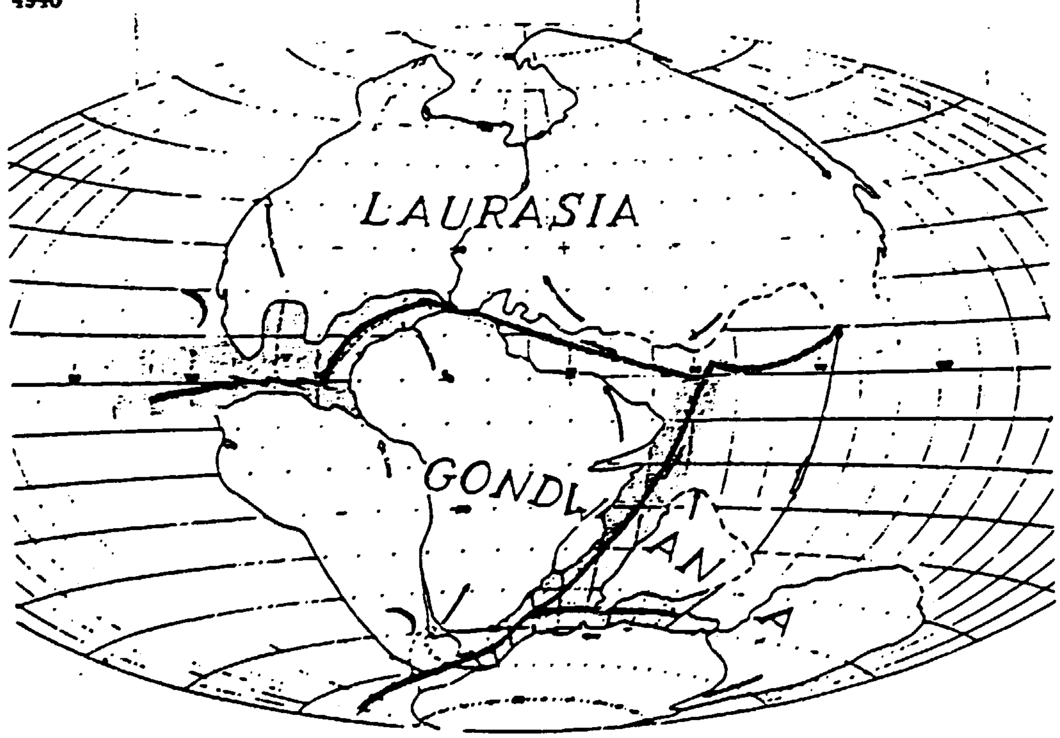


Fig. 3. Initial rifting of Pangaea as of the end of the Triassic 180 m.y. ago. Open arrows are vectors showing the drift that occurred during the entire Triassic.

Estensione in longitudine continenti ~ 180°
(inizio del cretaceo)

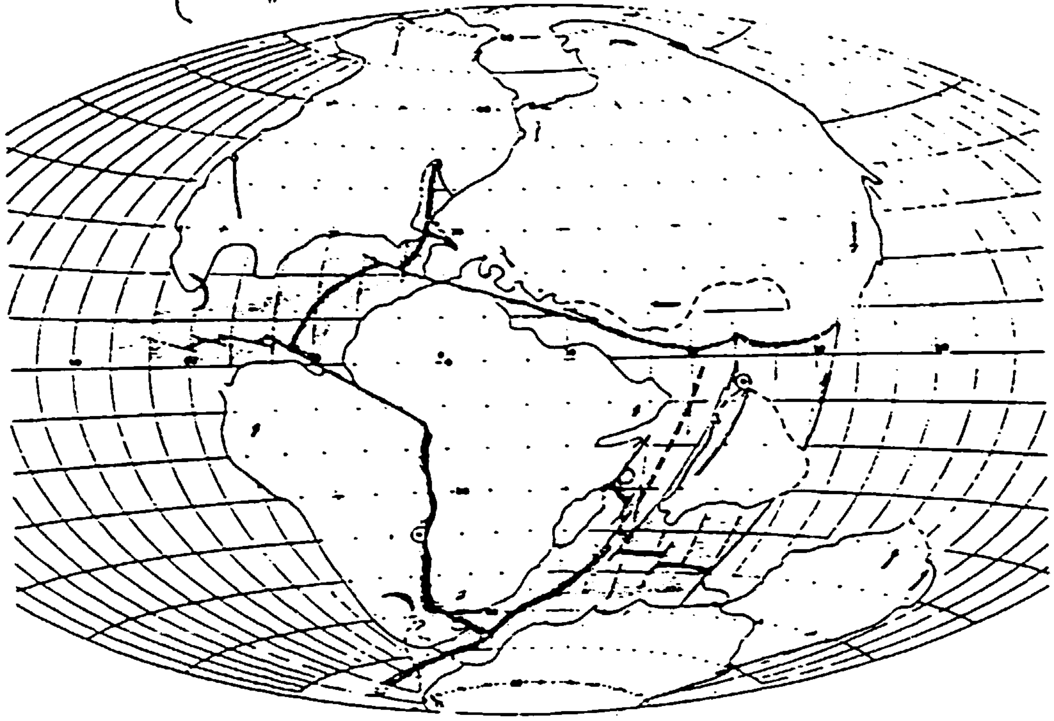


Fig. 4. The continental drift dispersion of the continents as of late Jurassic, 135 m.y. ago.

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Estensione in longitudine continenti ~ 220°
(fine del cretaceo)

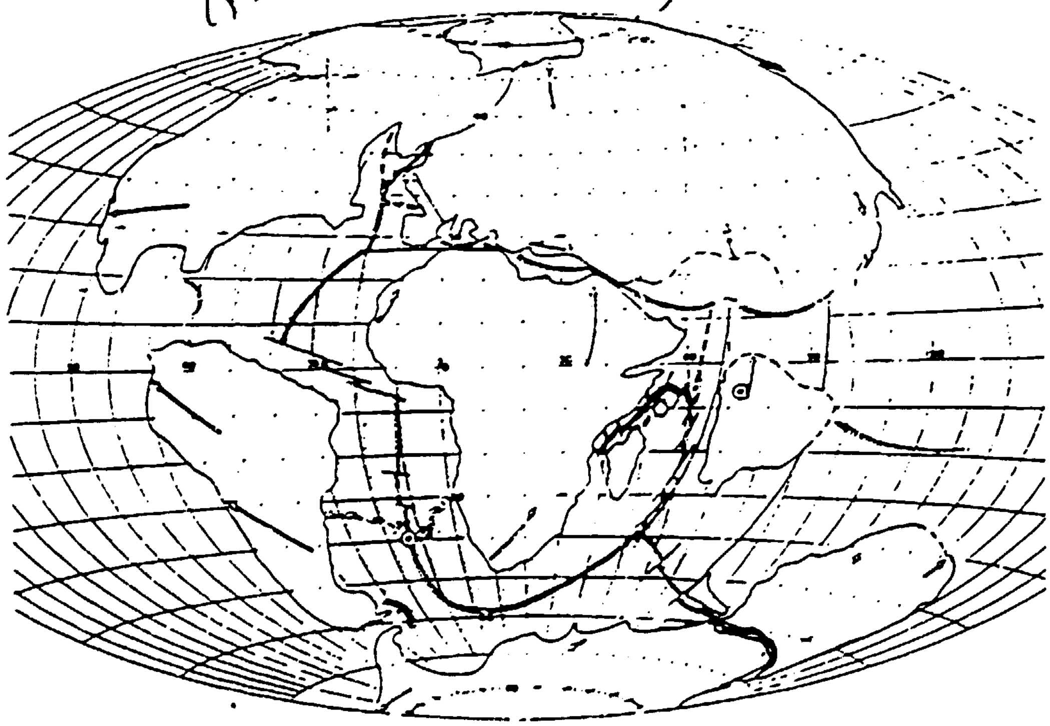

Fig. 5. The continental drift dispersion of continents as of the end of the Cretaceous. 65 m.y. ago.

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INIZIO Terziario (Cenozoico)

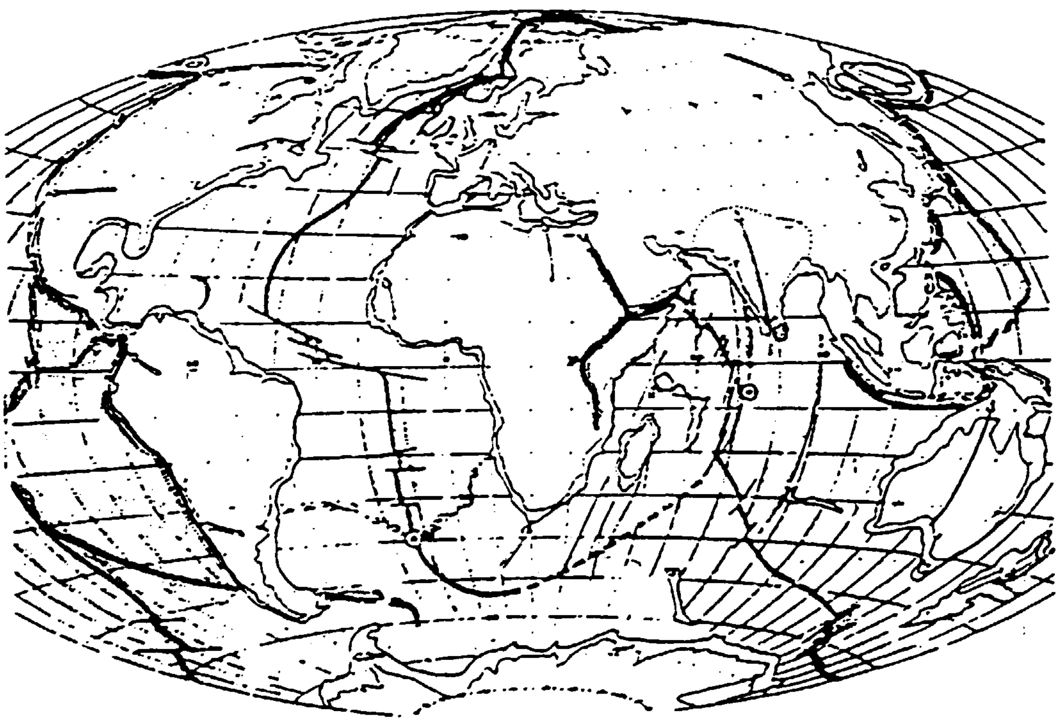
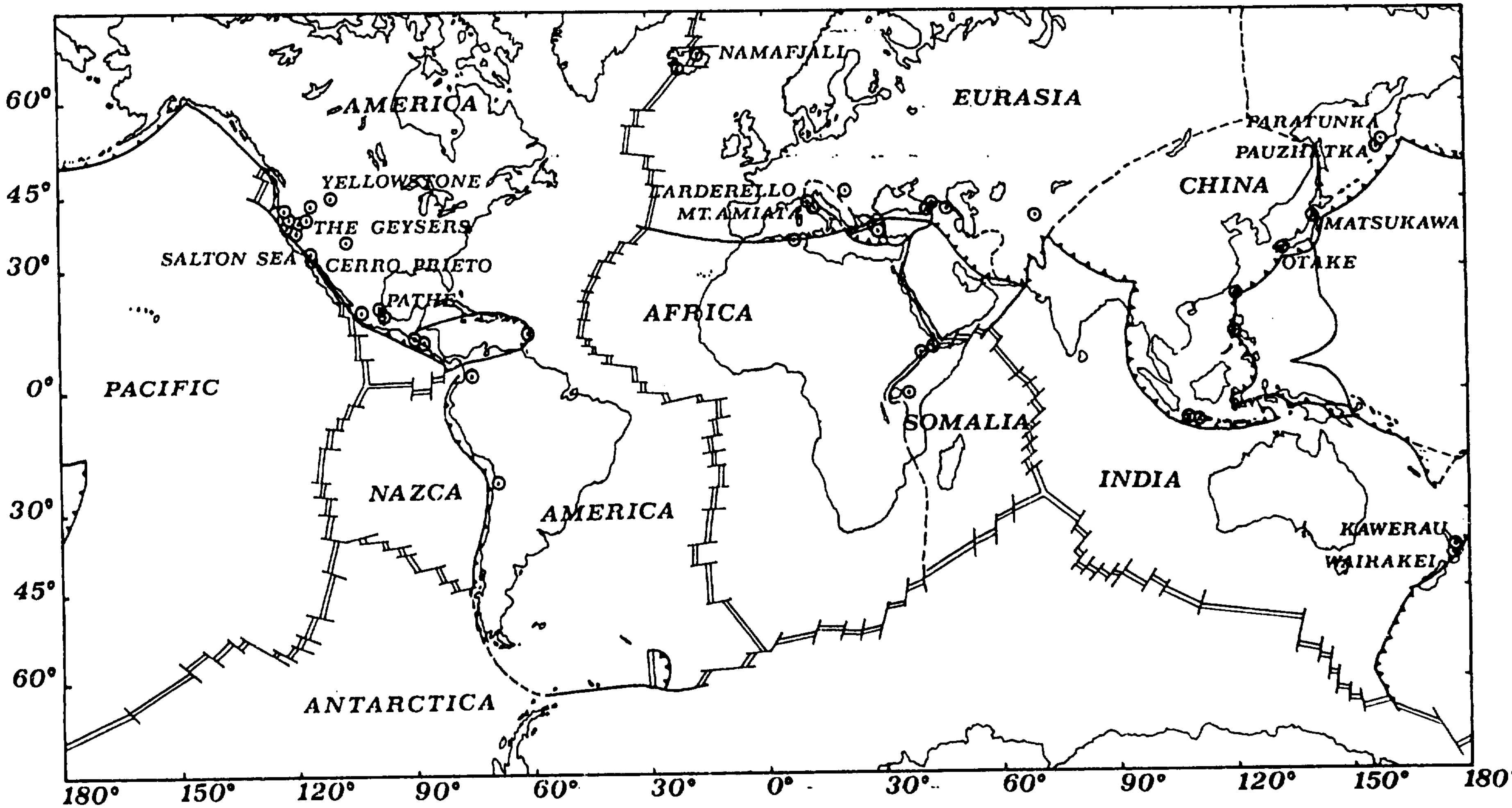


Fig. 6. The position of continents today showing the amount of sea-floor spreading, etc. during the Cenozoic.



NAMAFJALL
EURASIA
AMERICA
60°
PARATUNKA
PAUZHETKA
YELLOWSTONE
TARDERELLO
MT. AMIATA
CHINA
45°
THE GEYSERS
MATSUKAWA
SALTON SEA
CERRO PRIETO
OTAKE
30°
PATHE
AFRICA
0°
PACIFIC
SOMALIA
INDIA
NAZCA
30°
AMERICA
KAWERAU
WAIRAKEI
45°
60°
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90°
120°
150°
180°

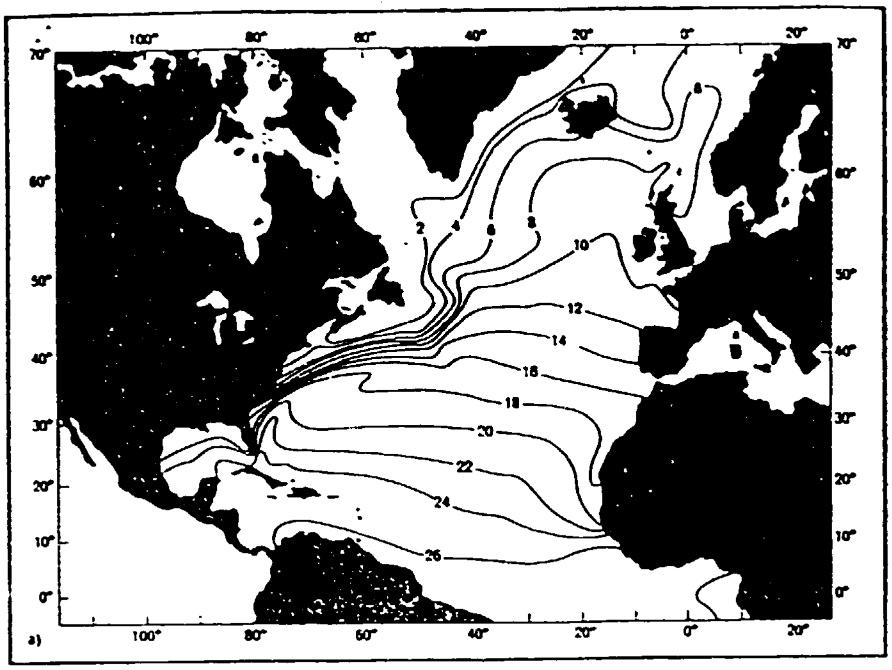
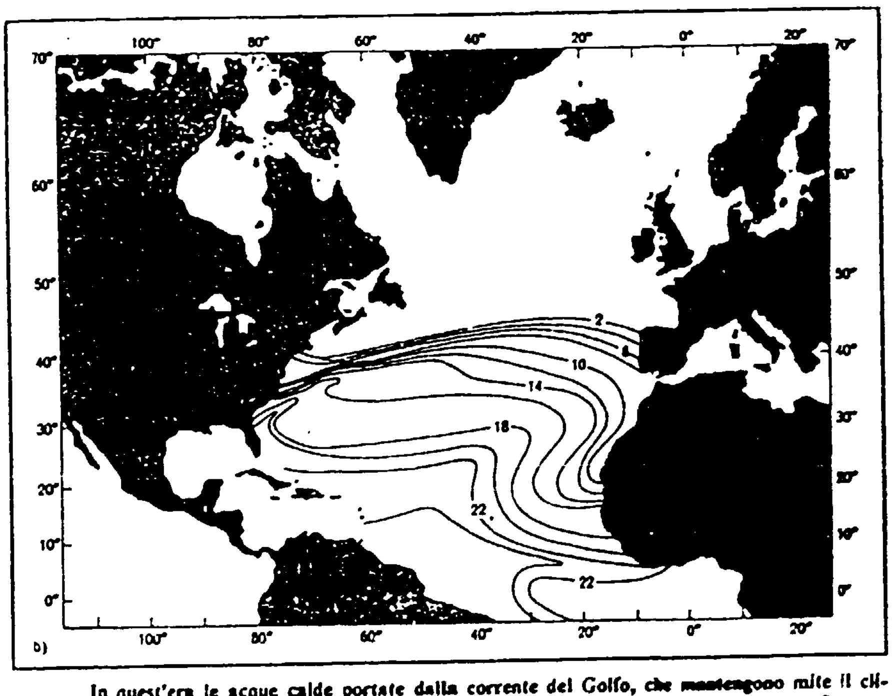


Fig.3 Mappe relative alla temperatura media della superficie nell'Atlantico settentrionale in due periodi: oggi (a) e 17 000 anni fa (b), cioè al culmine dell'ultima era glaciale.



In quest'era le acque calde portate dalla corrente del Golfo, che mantengono mite il clima oggi in Inghilterra, Irlanda ed Europa settentrionale, erano spostate a sud della Spagna.

GLOBAL HYDROLOGICAL CYCLE

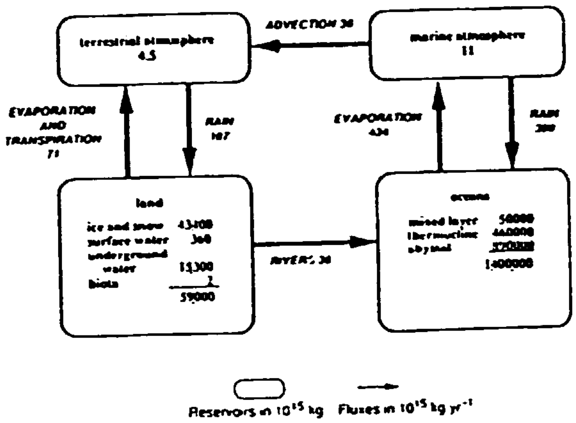


FIG. 1 Estimates of the global water cycle and its reservoirs. The accuracy of several of its components is poor, resulting in a closure error for the whole cycle of about a factor of two. The obvious interactive nature of the cycle makes it impossible to reduce current closure errors without studying the whole cycle. This diagram is based on Fig. 1 from ref. 5.

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- Atmospheric RESERVOIRS ARE SMALL.
- Fluxes between Atmosphere and oceans/Land are larges
  ↓
- Recycling of water in The Atmosphere rapid

→ Recycling $\left(\frac{1}{\tau_w}\right) = \frac{\text{Total yearly precipitation}}{\text{Atmospheric storage}} = \frac{505}{15.5} = 33/y$

→ Residence time $\tau_w = \left(\frac{1}{33}\right)$ year $\simeq$ 11 days

→ OVER LAND 1/3 of rainfall comes from MARINE EVAPORATION, driven by winds.

→ 2/3 from evaporation from LAND.

Earth System

- Termodynamically a "Closed" system
  [Exchange only energy with rest of the world]

- Out of termal equilibrium with the rest of the world ($T_w \simeq 3°K$), due to solar radiation

- Seen from outside, in optical wavelenghts, as a luminous body, due to partial reflection of solar radiation
  [Reflection coefficient (albedo) $\alpha = 0,3$]

- Seen from outside, in infrared wavelenghts, as a warm black body with absolute temperature $T_B = 255°K$ ($-18°C$)

Problem!

The mean temperature of earth's surface is greater $T_S = 288°K$ ($+15°C$)

$$T_S - T_B = +33°C$$

Why?

"Greenhouse effect" played by the troposphere

Ice-core record of atmospheric methane over the past 160,000 years

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† Arctic and Antarctic Research Institute, Beringa Street 38, 199226 Leningrad, USSR

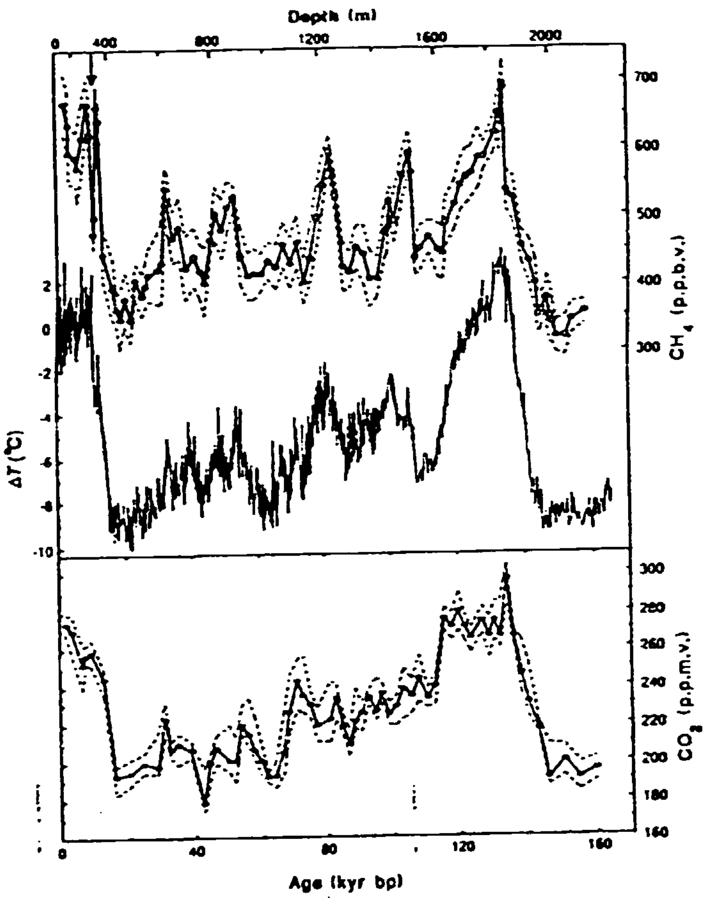


FIG. 1 Vostok ice-core records. Upper curve: CH_4 record. Circles indicate mean values. The envelope shown has been plotted taking into account the various uncertainty (2σ) sources. The arrow corresponds to the Younger Dryas CH_4 oscillation. Middle curve: Isotope surface temperature record as a difference from the modern temperature value (−55.5 °C, ref. 8). For comparison, the lowest curve shows the Vostok CO_2 record[8]. The timescale applies to all three records. The depth scale applies only to the CH_4 and CO_2 curves, because of the difference in age between air bubbles and surrounding ice.

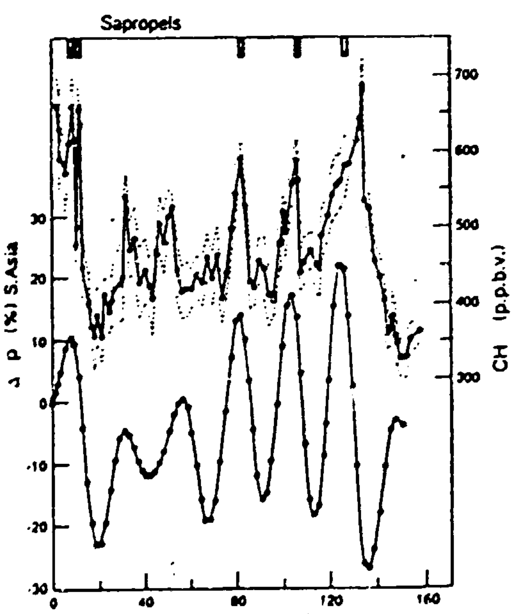


FIG. 3 Upper curve: Vostok CH_4 record plotted against age. Circles correspond to mean values and envelope to the analytical accuracy (2σ). Lower curve: changes of precipitation (in per cent) over southern Asia simulated by general circulation models[28]. 0% corresponds to modern boundary conditions. The vertical bars at the top of the figure indicate the presence of sapropels in the East Mediterranean Sea[31,32].

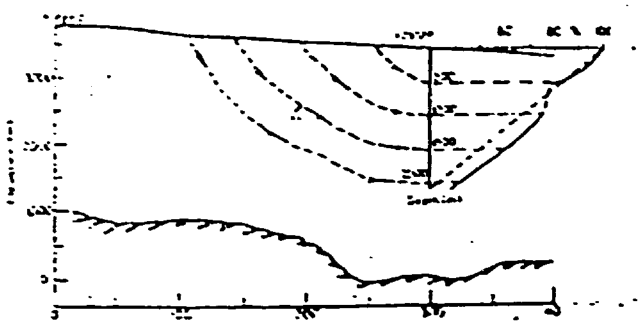


Fig. 2 Surface and bedrock topography along the Ridge B-Vostok axis (lower curve) and the thinning function (top right) expressed as a percentage of the initial thickness, with (solid line) or without (dotted line) taking into account this topography.

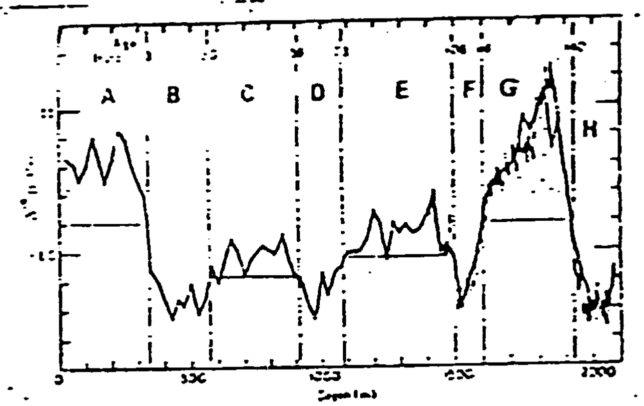


Fig. 1 Oxygen-18 versus depth in the Vostok ice with the definition of the successive stages and indication of the ages corresponding to the limits between these stages. The thick line is drawn from discontinuous data (one for each 25 m), the thin line corresponds to a continuous sampling between 1,400 and 2,053 m. For explanation of A-H, see text.

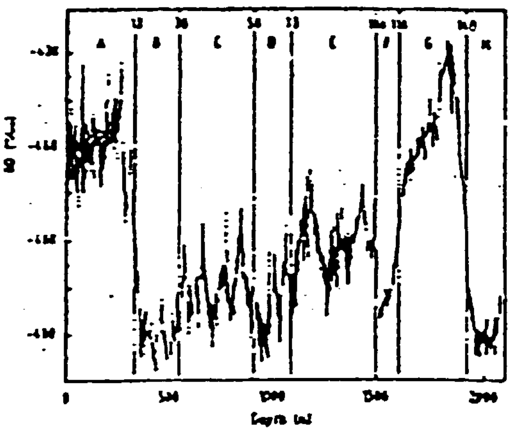
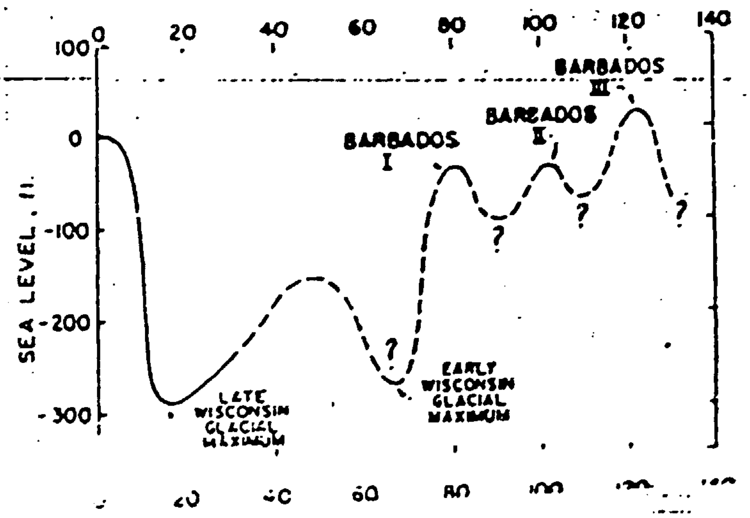


Fig. 1 Deuterium content (in ‰ w.r.t. SMOW) against depth in the Vostok ice core with successive stages as defined in ref. 4 and the ages corresponding to the limits between these stages.



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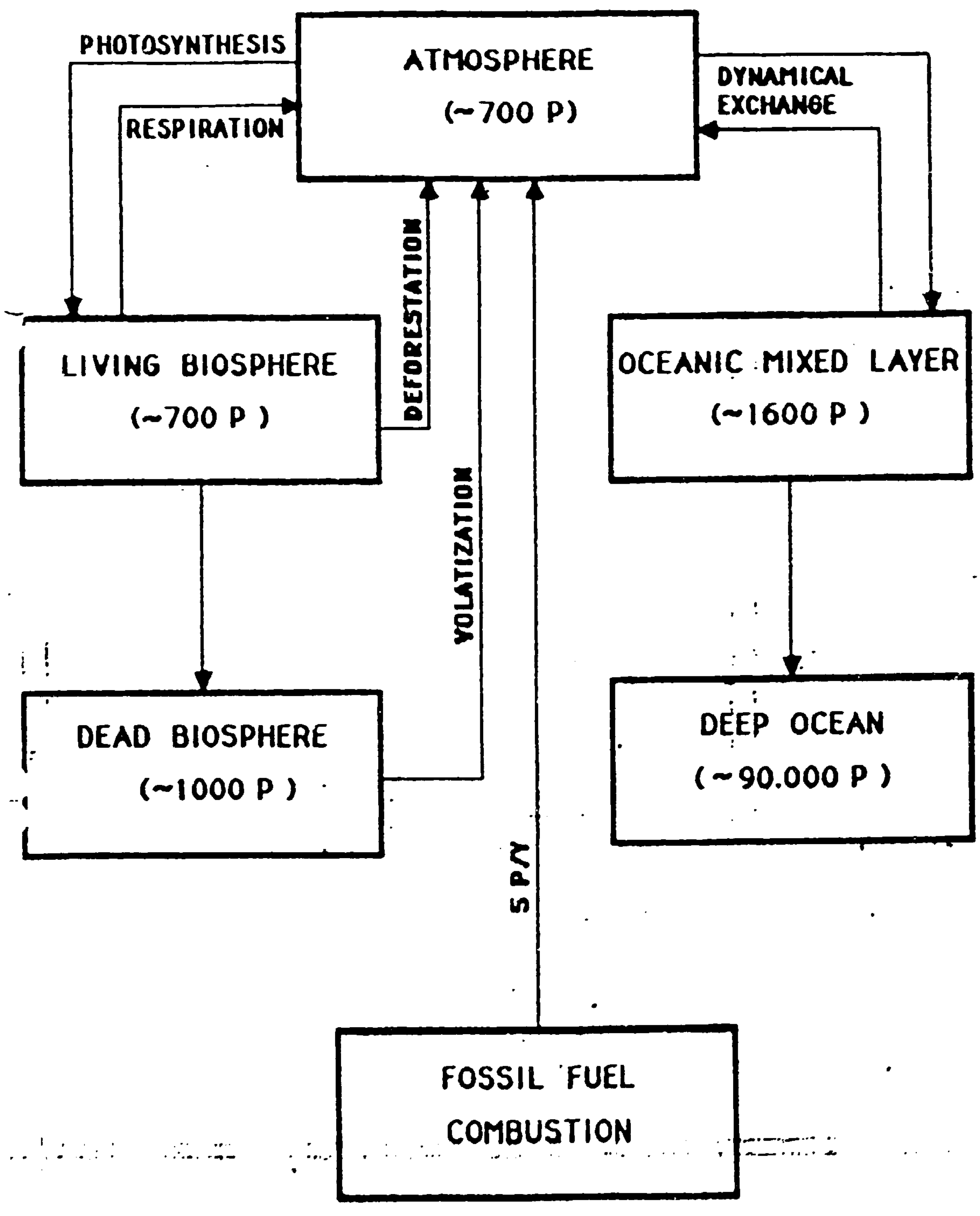
SUB - SYSTEMS CONTAINING AND EXCHANGING CO_2



1P = 10^9 t of carbon

Fig. 3

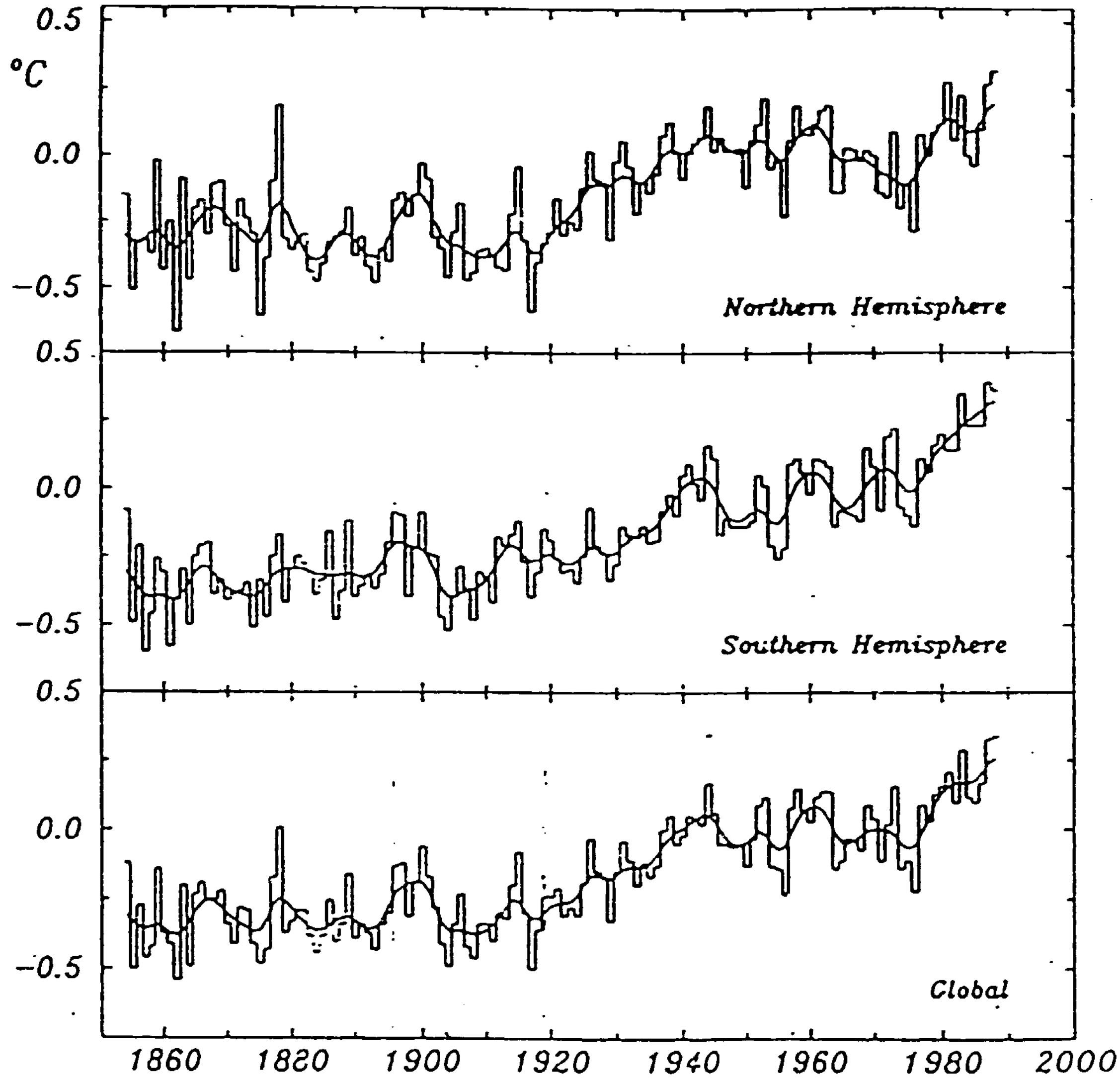


Figure 15. Instrumentally recorded temperature variations compiled from a time-varying network of continental air temperature measurements and sea-surface temperature records (from Jones et al., 1991).

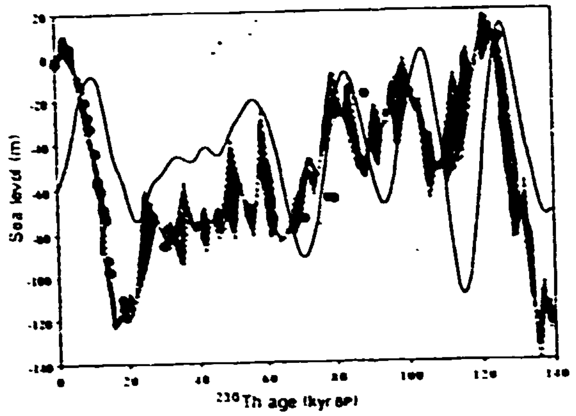


FIG. 1 *A. palmata* palaeodepth plotted against Th-U ages measured by mass spectrometry. To reconstruct this sea-level curve we applied linear corrections for uplift by normalizing the last interglacial high stands to 7 metres above the present sea level (see text). Barbados data are listed in Table 1 and ref. 15, data for samples C1 and C4 from Haiti are given in ref. 15. Dashed-dotted line, normalized $\delta^{18}O$ curve determined by Shackleton[20]; dashed line, normalized $\delta^{18}O$ curve determined by Labeyrie *et al.*[18]; solid line: 65°N summer insolation[21]. ($\delta^{18}O$(‰) = [($^{18}O/^{16}O$)$_{sample}$/($^{18}O/^{16}O$)$_{standard}$]-1, where standard is PDB.)

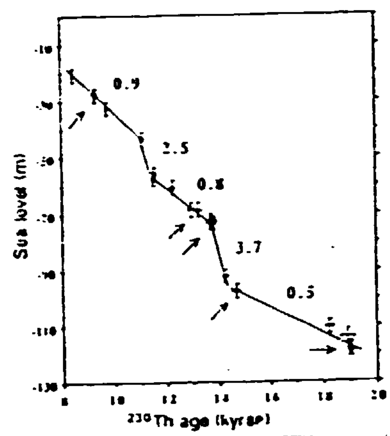


FIG. 2 Sea level during the last deglaciation. All samples are *Acropora palmata*. The U-Th age errors are quoted at the 2σ level. The samples marked by arrows correspond to duplicate analyses of the same coral sample by U-Th mass spectrometry. All duplicates are in agreement within error. A constant error of ±2.5 m has been assumed for the sea level. The numbers correspond to the melting rates (metres per century) calculated from slopes of the linear regressions.

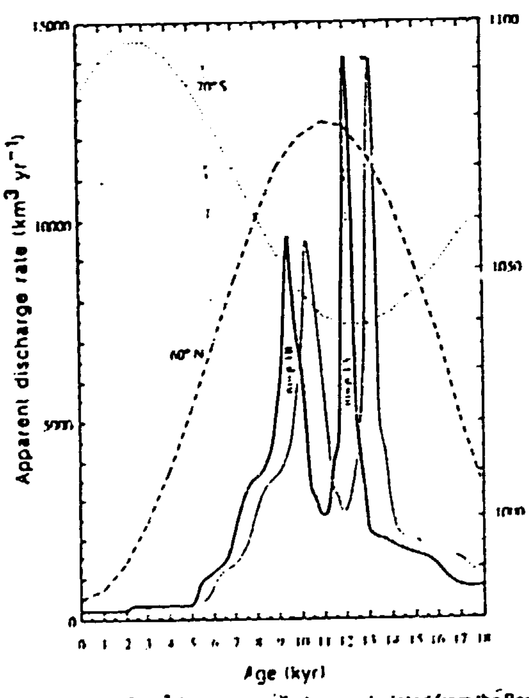


FIG. 3 The rate of glacial melt-water discharge calculated from the Barbados sea level curve compared to summer insolation. The discharge curve (thick line) is plotted according to radiocarbon years uncorrected for secular changes in atmospheric ^{14}C. Converting radiocarbon years BP to calendar years BP using the calibration in ref. 15 shifts the ages of mwp-IB and mwp-IA as shown by the thin line. Our preliminary $^{230}Th/^{234}U$ dates indicate that this correction is too small for mwp-IA (E. Bard, B. Hamelin and R.G.F., manuscript in preparation). By comparison, the insolation at 60° N (dashed line) and 70° S latitude (dotted line) are plotted against absolute time[14].

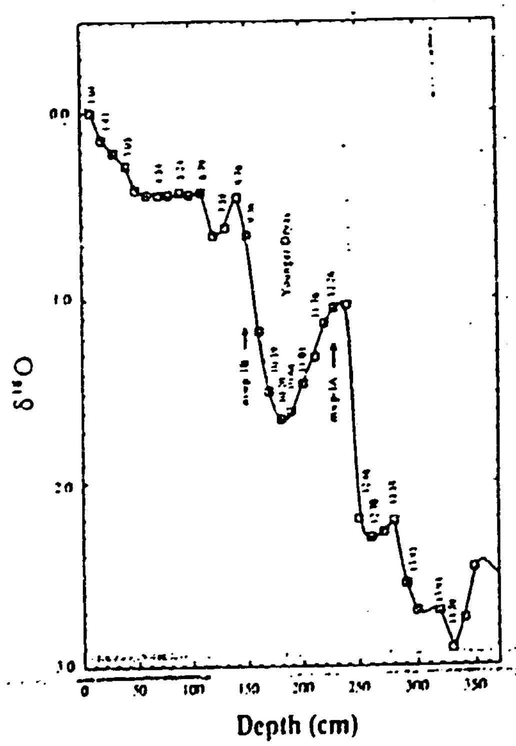


FIG. 4 The AMS ^{14}C-dated oxygen isotope record of *G. bulloides* from core SU81-18 located offshore of Portugal[12,34]. The AMS-^{14}C ages have been corrected for local seawater $\Delta^{14}C$ by subtracting 400 yr from the measured radiocarbon ages[9]. The estimated depth of mwp-IA and mwp-IB are marked by arrows.

Conclusions

- Today a forecast of the increase of earth's temperature is based on the result of the climatological models.

- The uncertainty for a doubling of CO_2 content in the atmosphere, with reference to pre-industrial level, is still very large, extending from 1,5°C to 4°C. —

- If the actual trend of accumulation of CO_2 in the atmosphere is maintained the doubling is going to take place around the middle of the next Century. —

- It is impossible to advance any hypothesis about the way in which the increase of temperature is going to develop, due to the possibility that the climatic system is going to follow a non-linear pattern. In addition we have still a poor understanding of all the feed-backs intrinsec to the system.

- Opinions expressed by scientists ranges from optimism (wait and see for a real indication) to pessimism (when the real indication materialize it will be too late). —

- What is clear is that any measure forseeable to control accumulation of greenhouse gases in the atmosphere is very costly. And very costly too any measure adressed to protect in advance the lowlands from the rise of the sea level.

- May be the next decennium will be enough a lapse of time in order: either to detect a real indication or/and to improve the quality of the answer of the climatological models.

- The real problem is that the consequences of a sea level rise are going to be with reference to the whole globe. Exactly for this reason and despite of this reason global consensus for undertaking any action looks very difficult, if not impossible. —

Professor Leopoldo Franco

Politecnico di Milano

COASTAL PROTECTION

INTERNATIONAL COURSE ON
"COASTAL ZONE MANAGEMENT"

ICS / Monselice (PD) 19-30 OCTOBER 1992

lecture on

COASTAL PROTECTION

by

prof. Leopoldo FRANCO

(POLITECNICO DI MILANO)
(Department of Hydraulic, Environmental & Surveying Engineering)

Contents:

- EROSION PROBLEMS
- POSSIBLE SOLUTIONS
} before lunch

- STRUCTURAL FEATURES (slides)
- EXAMPLE OF NEW PROTECTION SCHEME
} after lunch

5.

Coastal erosion keeps many coastal managers quite busy...

WHY PROTECTION ?

Manager of coastal area:
- Keep zone free
  allow the sea some "play-ground"

Owner of coastal hotel:
- stand very close to the sea (pleasant view for guests)
- if damage: blame the manager of coastal area...

Society:
- has to pay!

- Proper risk analysis
- Cost/Benefit
- Different standards { single house; large hotel; important road; safety of population }

"New" developments → proper limits
existing situation → risks too high

task of coastal engineer: REDUCE THE RISKS!

FACING A COASTAL PROBLEM...

1. STUDY THE PROBLEM BACKGROUND (understand basic natural processes)
1b. DO IT ON A LARGER AREA!
2. CONSIDER ALTERNATIVE SOLUTIONS
3. PREDICT THEIR MORPHOLOGICAL CONSEQUENCES ←

1. FIND REASONS OF EROSION (short or long term)
   1. LONGSHORE SED. TRAN. GRADIENT
      a) Natural : climatic changes, convex planshape
      b) Man-made : upstream constructions (harbours, piers, inlets; dams)

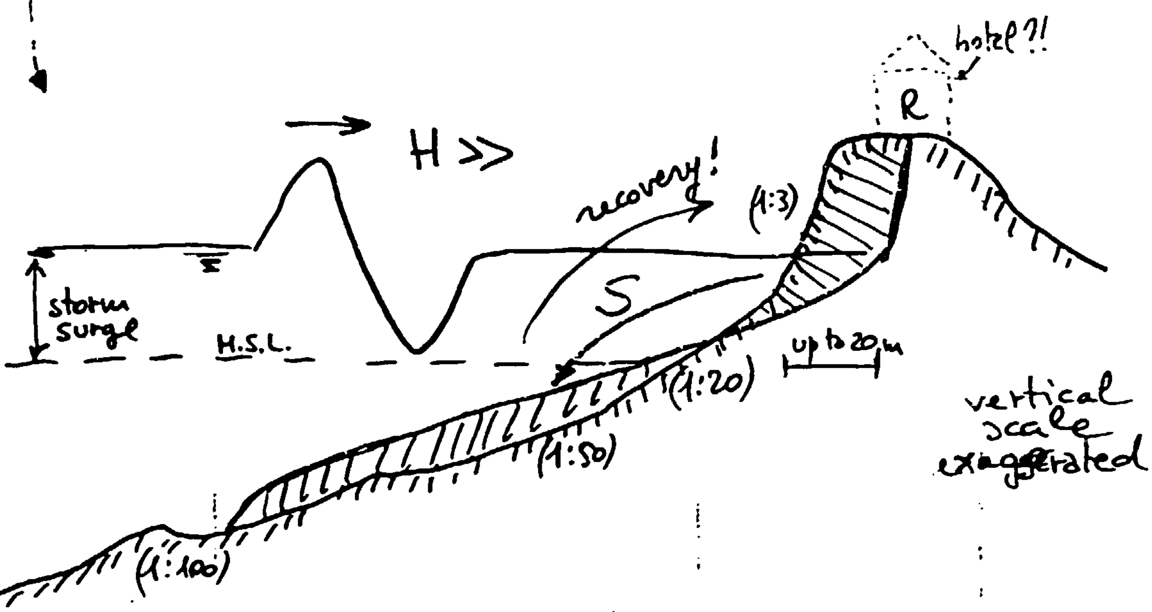
   2. OFFSHORE SED. TRAN.
      a) Natural : submarine canyon, sea level rise, storm erosion
      b) Man-made : mining, subsidence, reflections from structures

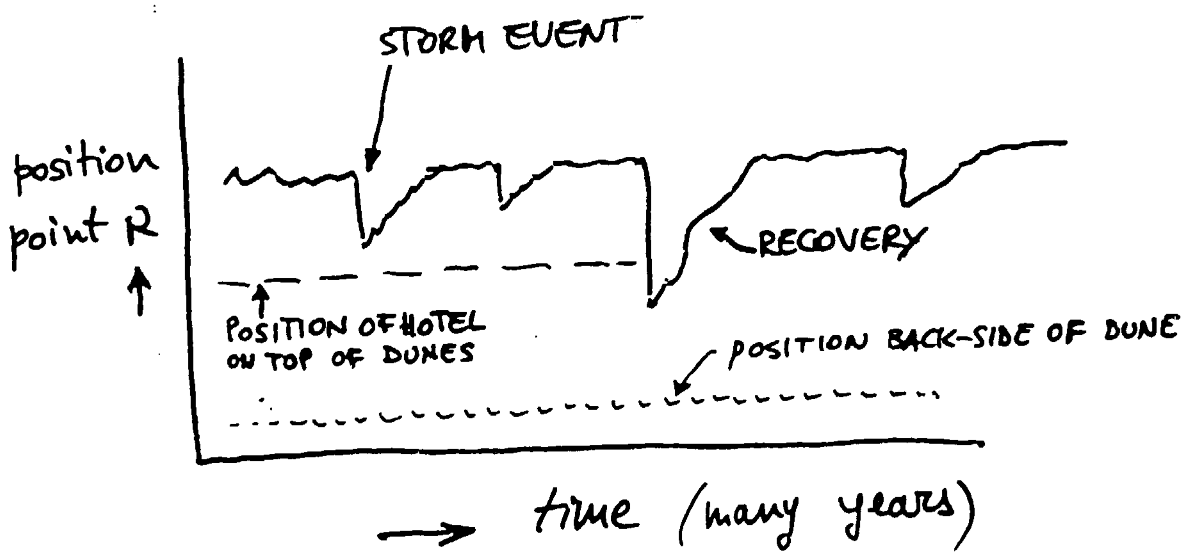
TWO BASIC EROSION PROBLEMS:

1. "<u>STRUCTURAL EROSION</u>" (mainly due to GRADIENTS IN LONGSHORE TRANSPORT
   long term

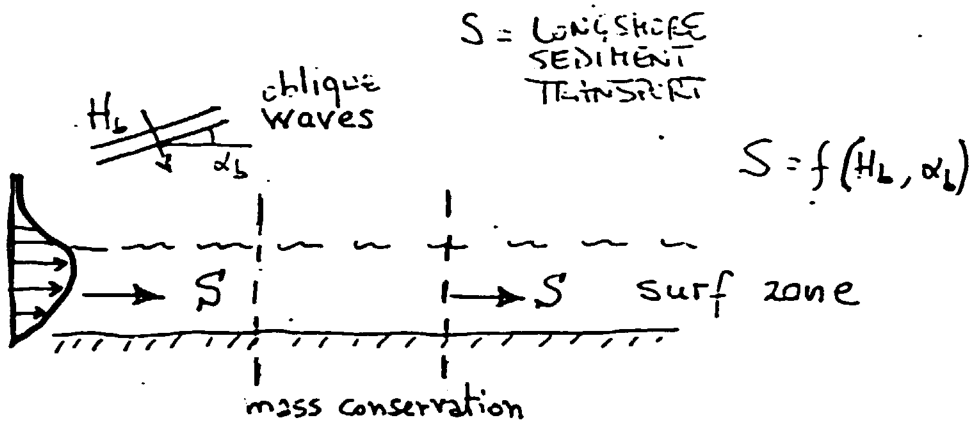
2. "<u>DUNE EROSION</u>" (due to OFFSHORE TRANSPORT + STORM SURGE with temporary beach profile change)
   short term

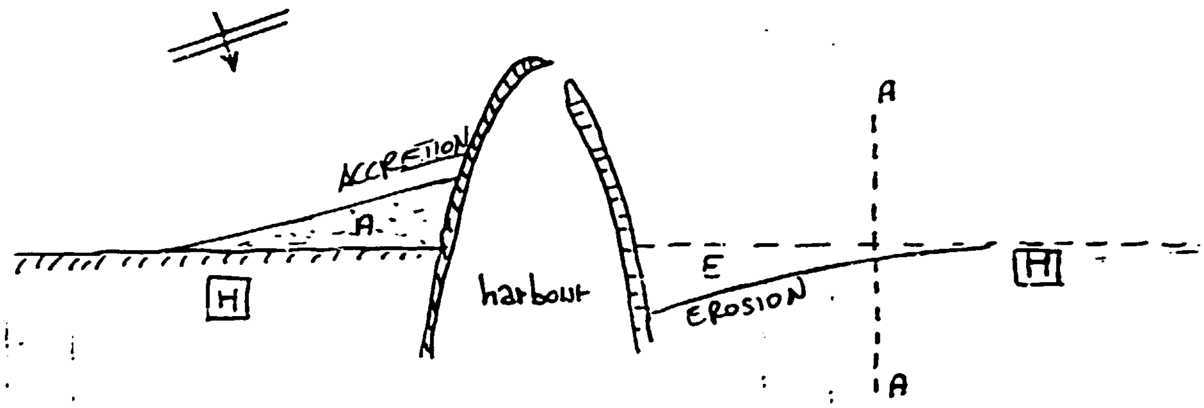
2:

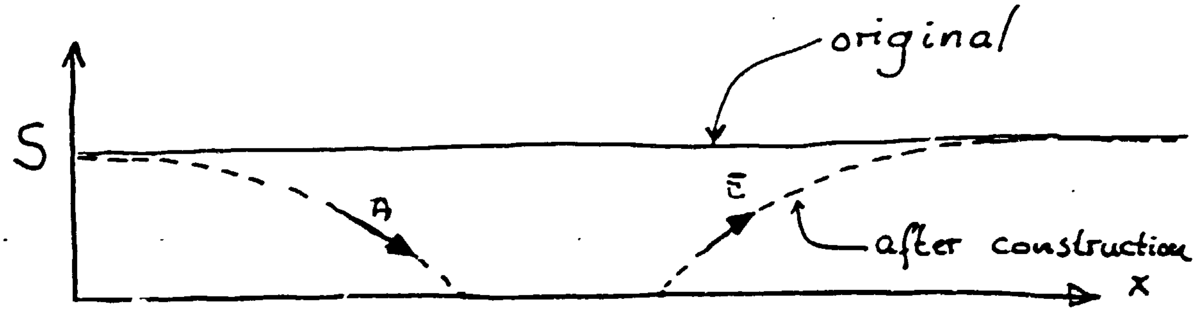




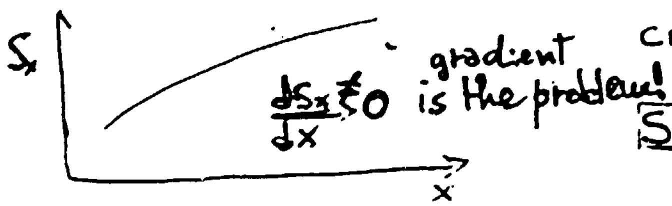
(1) Examples of structural erosion





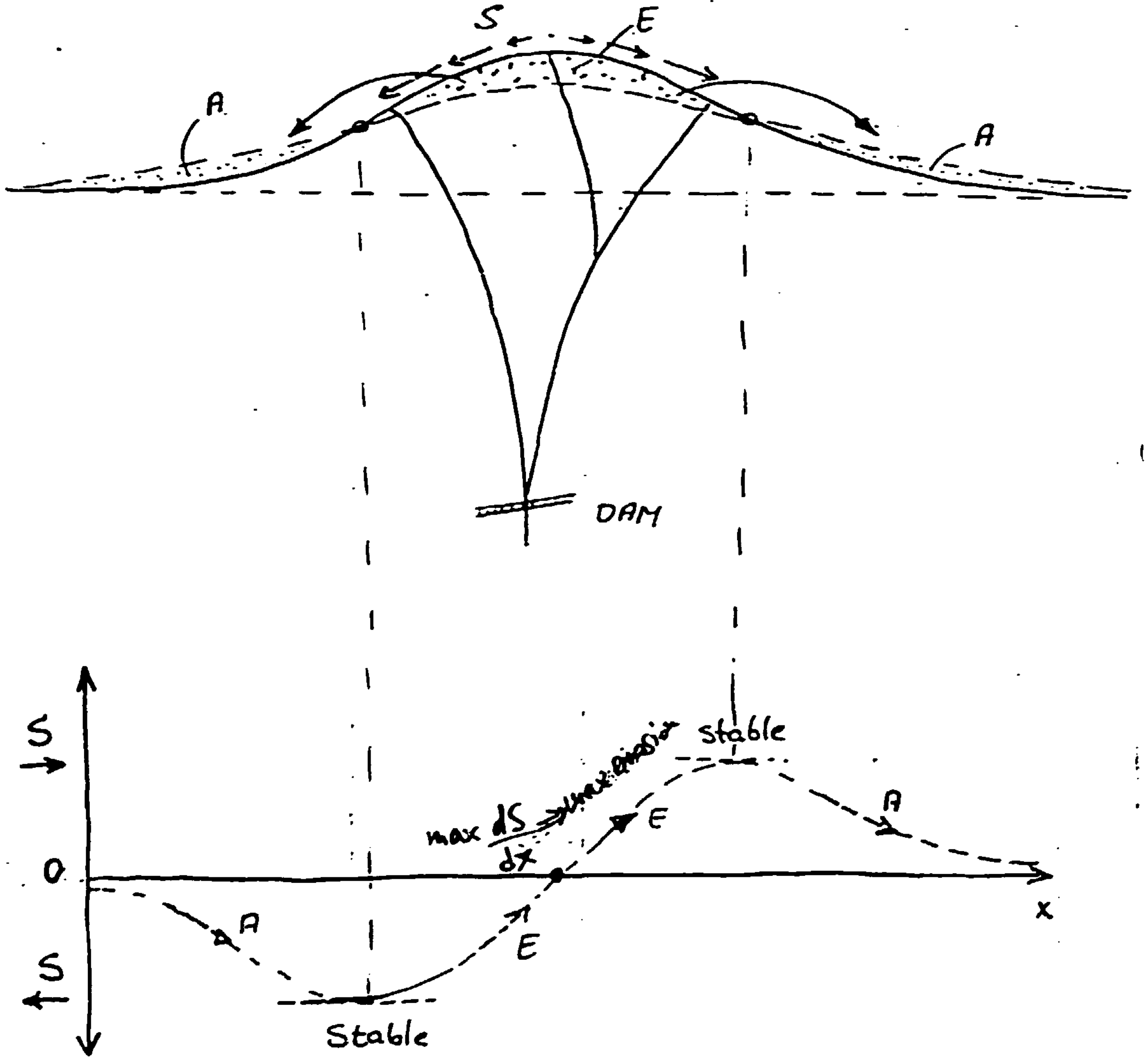


Loss of [illegible] from cross-s[illegible].



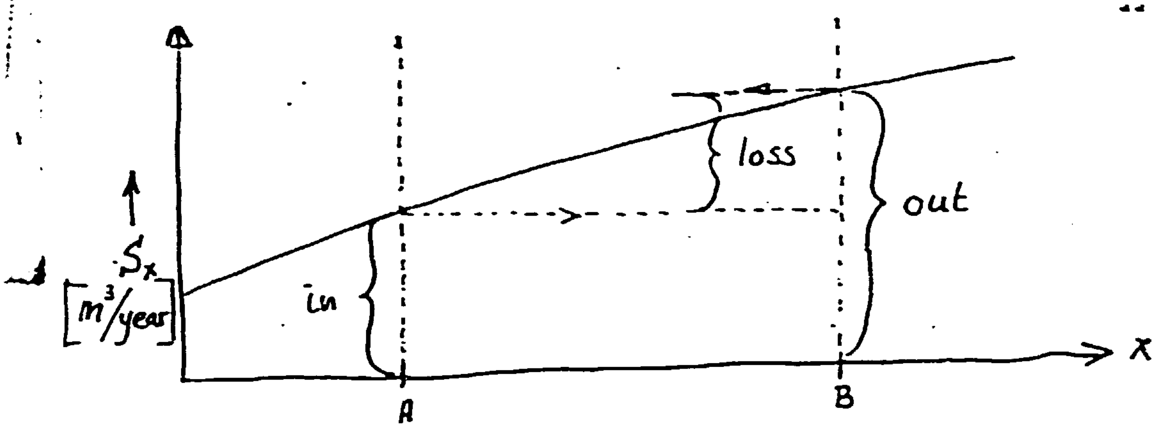
Structural erosion

2nd example
"convex planshape"
(river delta)



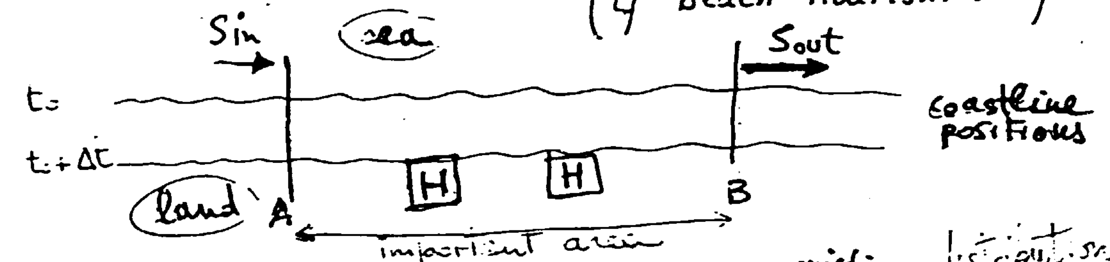
Loss of
sand from cross-section

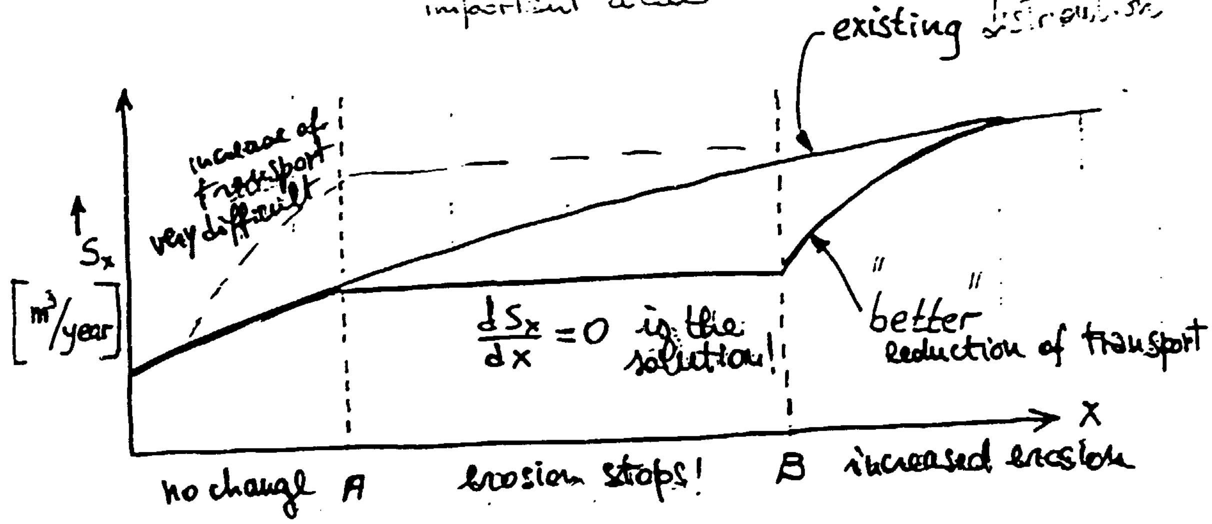
<u>Structural erosion</u>



Loss out of area AB

(if beach nourishments)





'Interference' in sediment transports

Change of existing curve in 'better' one

COUNTER-MEASURES against coastal erosion

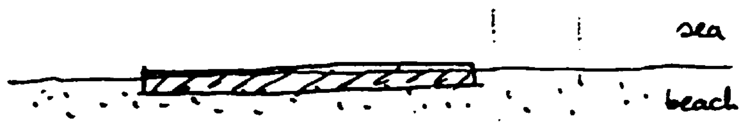
TWO TYPES OF SOLUTIONS :

a) WITH constructions (seawalls, groynes, offshore breakwaters)
[curing the CAUSE]

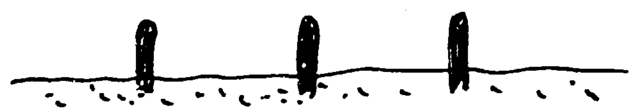
b) WITHOUT constructions (beach nourishment)
[curing the SYMPTOMS]

a) Can we affect the boundary conditions ?
- Reduce storm surge : NO !
- Reduce wave height : POSSIBLE (eg. detached barrier)

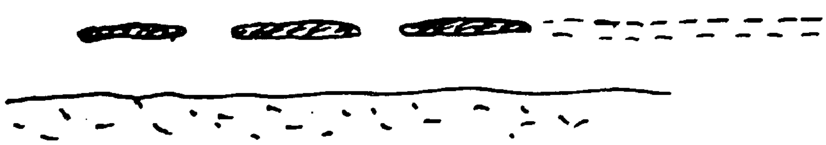
Seawall
(shore parallel structures)



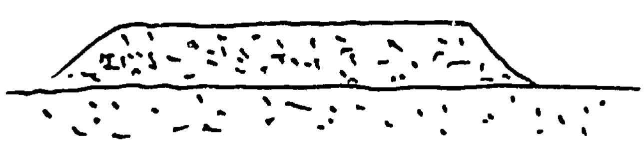
Groynes



Offshore breakwaters
(emerged or submerged)



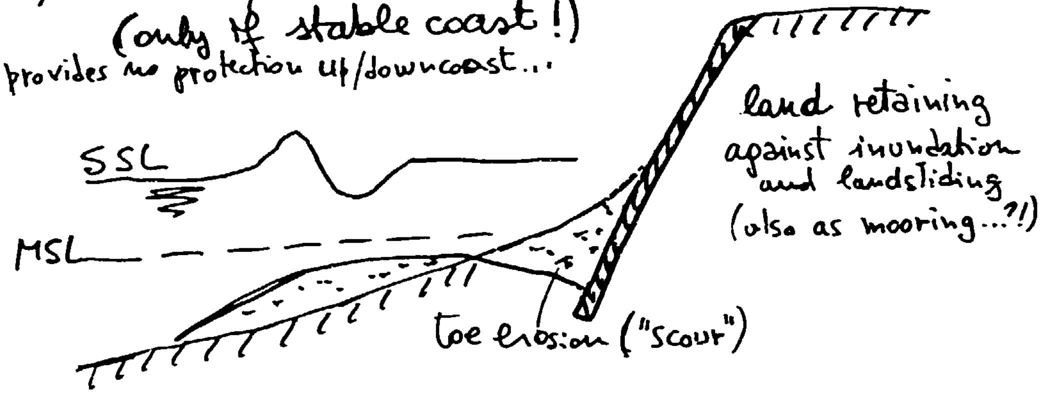
Beach nourishment



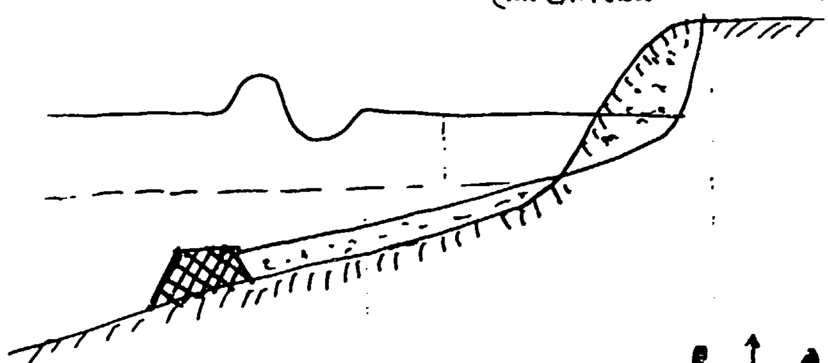
+ Combined systems

Solutions against "DUNE EROSION" (2)

1) seawall/revetment/dikes
(only if stable coast!)
provides no protection up/downcoast...

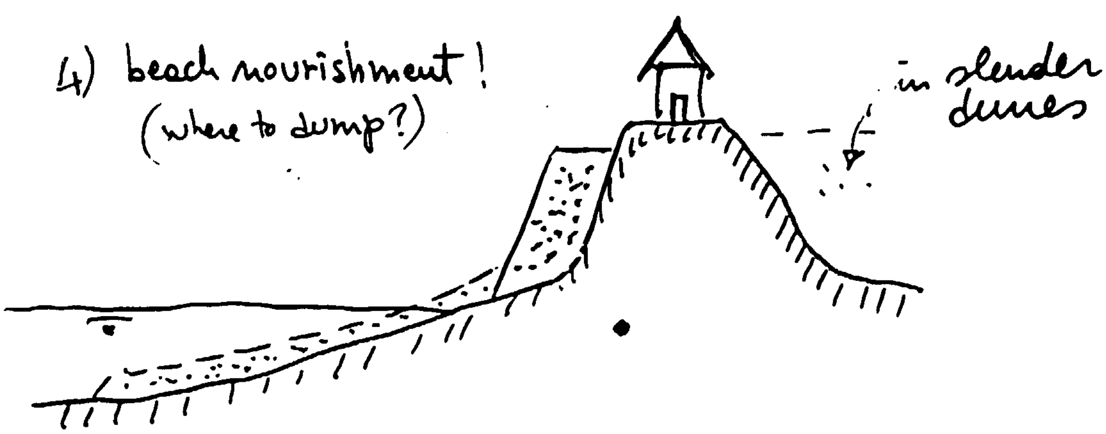


2) submerged breakwater (not effective)
(in extreme conditions)



3) groynes (not effective)

4) beach nourishment!
(where to dump?)

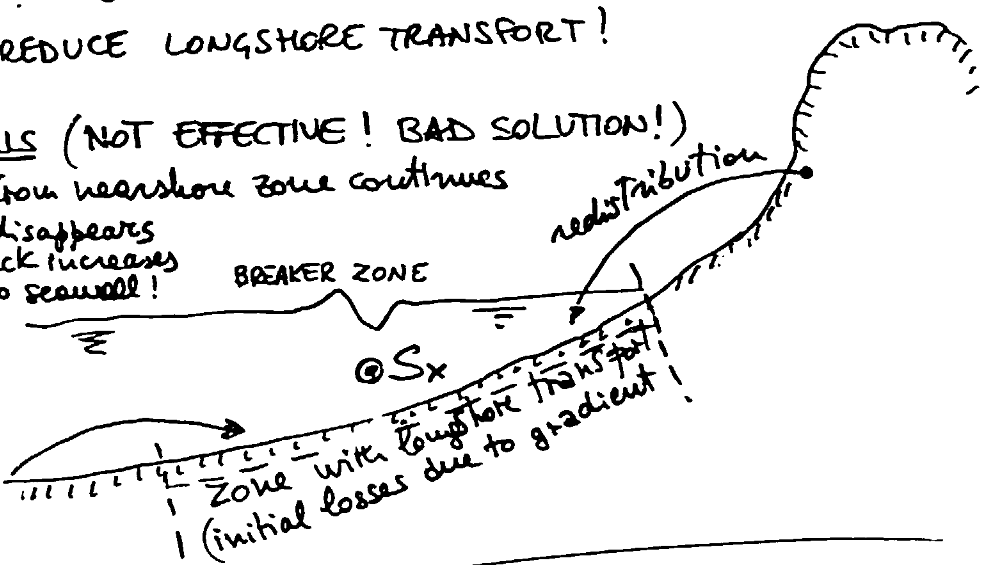


Solutions against "STRUCTURAL EROSION" (1)

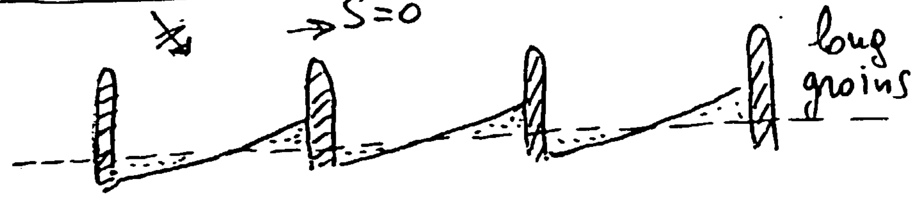
AIM: REDUCE LONGSHORE TRANSPORT!

1) SEAWALLS (NOT EFFECTIVE! BAD SOLUTION!)

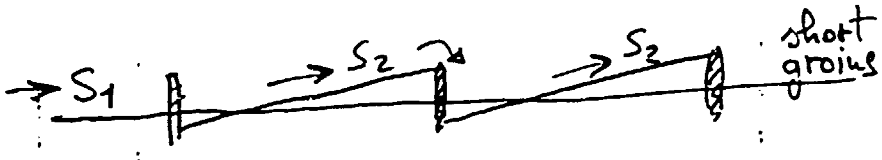
- loss from nearshore zone continues
- beach disappears
- wave attack increases
- damage to seawall!



2) GROYNES

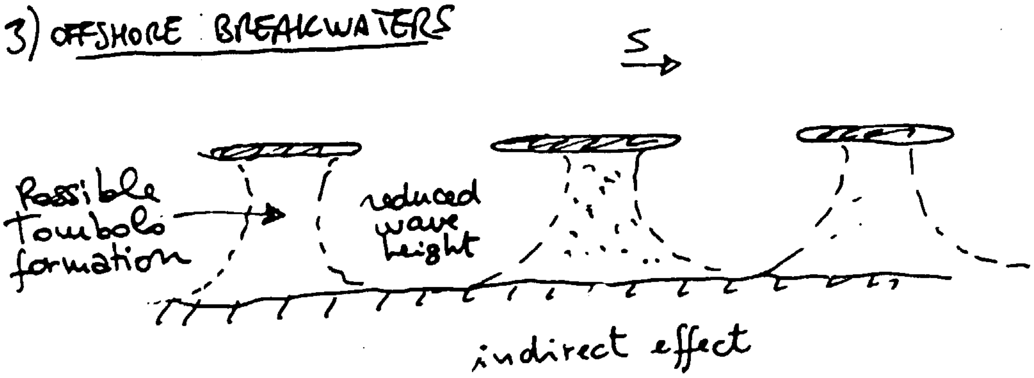


2a zero-transport solution



2b shoreline rotation $S_2 < S_1$

3) OFFSHORE BREAKWATERS

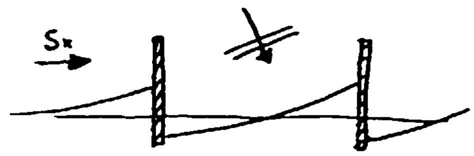


GROYNES (GROINS IN American English...)

— SHORE-PERPENDICULAR STRUCTURES

— TO TRAP LITTORAL DRIFT (IF EXISTING) (REDUCING LONGSHORE TRANSPORT RATE)

• INTERACTION NOT FULLY UNDERSTOOD!



→ MORPHOLOGICAL EFFECTS:

• "Saw-tooth" pattern

Displacement of erosion downdrift

• Simple prediction methods (SPM, 1984)

Effectiveness depends on percentage of S_x stopped function of length - height - spacing of groynes

General guidelines from literature review (Summers-Fleming, 1983)

- LENGTH mostly long - all across breaker zone
- SPACING range 1 to 4 times the length
- HEIGHT generally 1 m above beach level - lower at seaward end possibly adjustable (removable panels)
- SHAPE straight - sometimes T-shaped or L or Y or ſ or ⫯
- ORIENTATION 90° to shoreline - sometimes 110° (20° downdrift)
- PERMEABILITY often impermeable, but also cheap pile rows

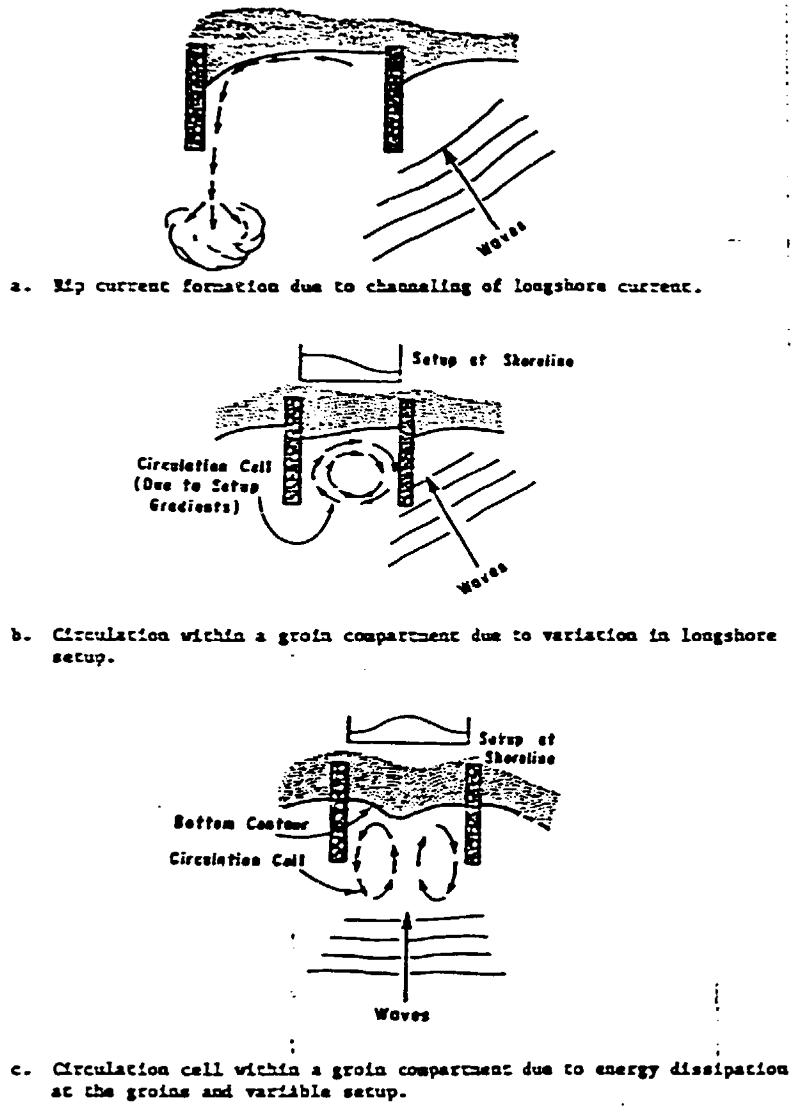


Fig. 8: Three mechanisms for creating rip currents between groynes (Dean, 1978)

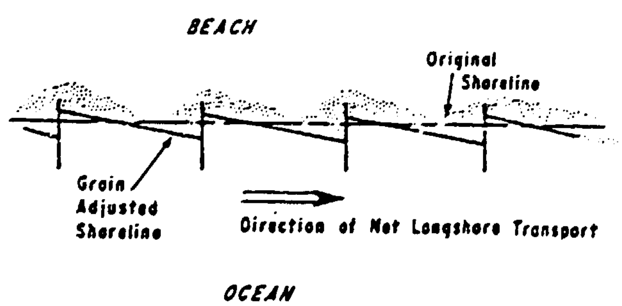
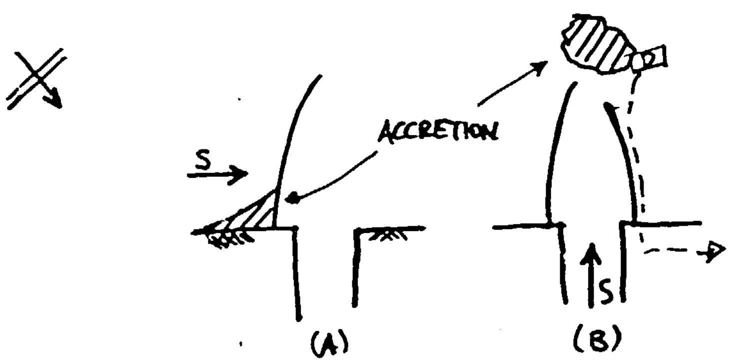


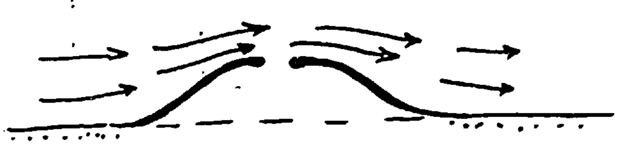
Fig. 9: General shoreline configuration in a groyne system

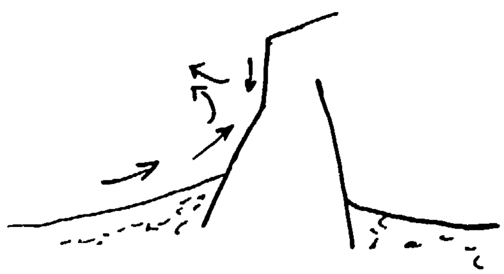
HARBOUR PLANNING

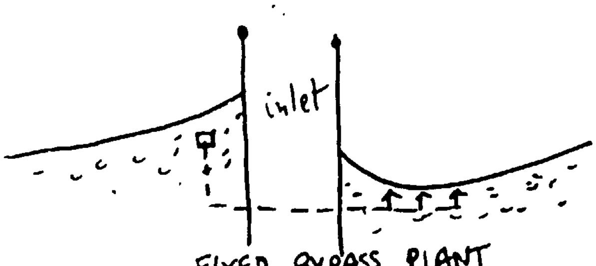
AIM
PROTECTION FROM
- SILTATION
  - FROM LONGSHORE TRANSPORT
  - FROM RIVER SEDIMENT SUPPLY
- WAVE ATTACK

SOLUTION
- PROPER LOCATION
- BREAKWATERS
- OPTIMUM LAYOUT
- BY PASS









BEACH NOURISHMENT (CUR manual, report 130)
Delft 1987

"BEACH FILL"
or
"PERCHED BEACH"

- input of material from external sources
- always good solution (no adverse morphological effects)
  the coastal "system" gets more sand!
- very flexible
- must be repeated regularly (curing the symptoms only!)
- no strange elements, looks so soft...

- Selection of sediment size:
  1) borrow material > native m. ⇒ steeper slopes, reduced transport
  2) native > borrow ⇒ flat slopes, increased transport

  overfill volume

- Methods of execution / dredging ⇒ dumping

  careful sand mining offshore!

  2 options with contrasting advantages:

A) ISOLATED DEEP PITS
- small area affected
- little effect on hydrodynamics

B) EXTENSIVE DREDGING AREAS
- little change in geomorphology
- easier faunal recovery
- bottom material unchanged

EXAMPLE OF ECONOMIC ANALYSIS

- 5 Km length of coast
- 20 m^3/m year "structural loss"
- 1 groyne costs say 500,000 US $

total loss per year: 20 x 5000 = 100,000 m^3/year

e.g. 20 groynes at 250 m intervals
costs: 20 x 500,000 = 10,000,000 $

Assume 7% interest rate:

10,000,000 x 0.07 = 700,000 $ interest per year

this could be spent for periodical nourishment!

100,000 m^3 of sand can be nourished at 7 $/$m^3$ ...!!
(without any investment cost ...)

MATERIALS FOR COASTAL STRUCTURES

ROCK: WEIGHT 0-10t ; MAX SLOPE 1:1.33 ; POROSITY 35-40%
SHAPE : Rough, angular, hard, compact, bulky ($l_{min} > 0.5\, l_{max}$)
UNIT WEIGHT $> 2.6\ t/m^3$ (limestone/silicious);
MAX WATER ABSORPTION = 2.5% (CIRIA-CUR Manual, 1991)

CONCRETE 1) UNREINFORCED (MASS CONCRETE)

Composition:
- POZZOLAN OR SLAG CEMENT (300-320 Kg/m^3)
- COMPACT, BULKY, ALCALI-ALUMINIUM RESISTANT AGGREGATES
- SAND WITHOUT SALT OR SILT/CLAY
- LOW WATER/CEMENT RATIO (40%)

LOW PERMEABILITY - HIGH COMPRESSIVE STRENGTH ($> 250\ Kg/cm^2$)
SPECIFIC WEIGHT $\geq 2.3\ t/m^3$ - PERFECT CURING HYDRATION
PREFABRICATION ! CASTING UNDERWATER WITH ADDITIVES (Hydrocal(R))
OR SMALL PIPES (12-16 cm diam.) emerging 1-3 m above M.S.L.

2) REINFORCED MINIMUM COVER 50 mm,
SPACINGS BETWEEN BARS > 2.5 D

CORROSION PROTECTION : - HOT GALVANIZATION
- EPOXY RESINS
- POLYMER CEMENT MORTARS

POLYPROPYLENE FIBERS
MECHANICAL VIBRATION

3) PRESTRESSED (vulnerable) DYWIDAG bars + spare empty cases

GEOTEXTILES filter performance (soil gradation)
durability : wear resistance
puncture and impact resistance
res. to ultraviolet damage
flexibility

STEEL vertical sheet-piles (LARSSEN - ROMBAS) temporary works

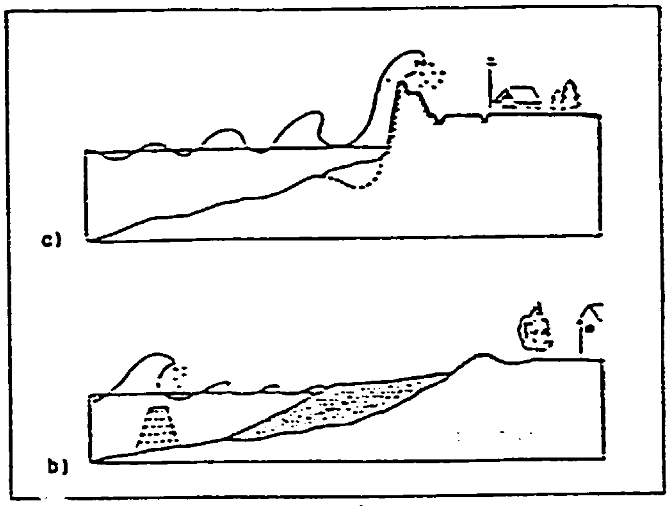
CORROSION PROTECTION : – HOT/COLD GALVANIZATION
(splash zone!) – TAR PAINTING
– CATHODIC (ZINC/ALUMINIUM ANODES or LOW TENSION CURRENTS)
– STAINLESS STEEL !
– PVC coated for gabions

TIMBER nice, easy to clean and replace, environ. friendly(?)
(IROKO!) variable performance – not durable
PRESSURE TREATMENT (ASPHALT / CREOSOTO OIL / GUNITE) against "fouling"....
weak points: (galvanized steel connectors)

SELECTION PROBLEMS

1. ECONOMY (near quarries ?)
2. DURABILITY – HYDRAULIC PERFORMANCE
3. ACCESSIBILITY (construction method) + TRAFFIC!
4. ENVIRONMENT → AESTHETICS
→ POLLUTION (air, water, acoustic)
→ LAND QUARRY

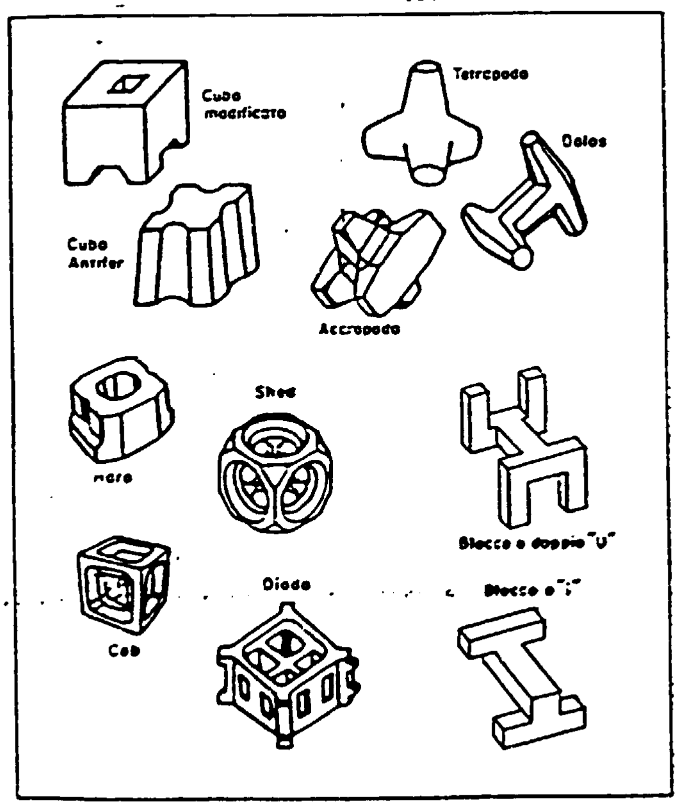
Coastal protection



OLD SCHEME

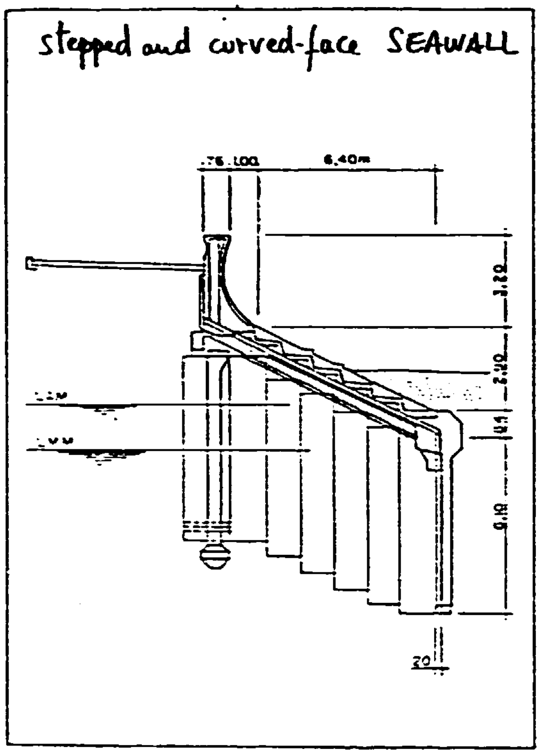
NEW SCHEME

1 - **Sistemi di protezione dei litorali: a) schema tradizionale; b) schema integrato.**



CONCRETE ARMOUR BLOCKS

12



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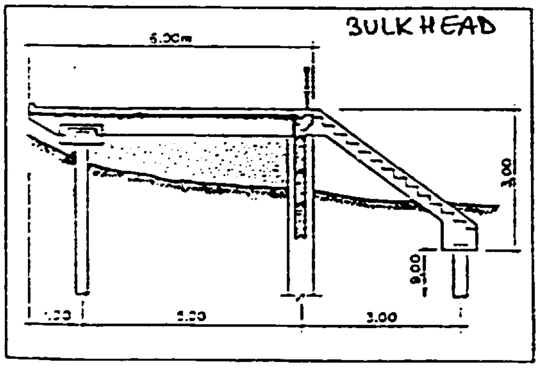

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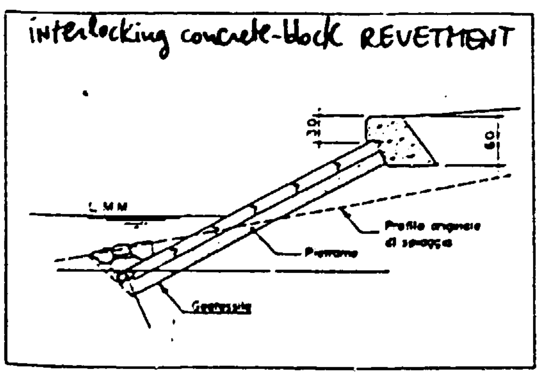

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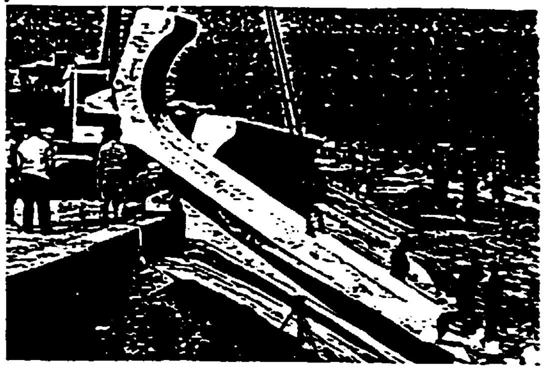

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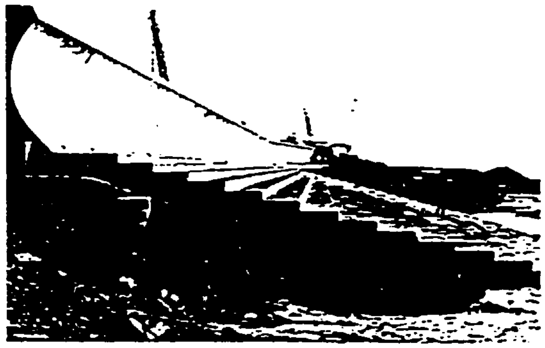

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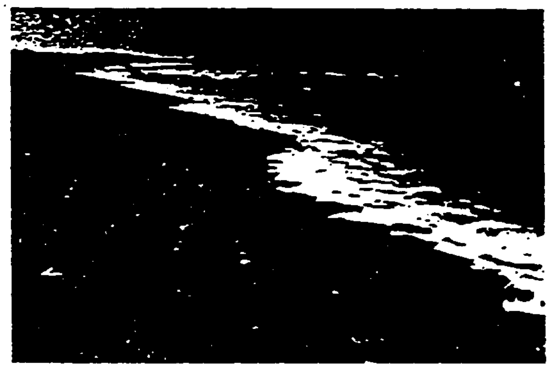


12 - Muro a gradoni con profilo concavo; 13 - Paratia di calcestruzzo con pali e scale d'accesso; 14 - Rivestimento tradizionale con piastre di calcestruzzo interconnesse; 15-16 - Realizzazione di opere di difesa aderenti con muro paraonde concavo; 17 - Rivestimento con elementi tipo «Basalton».

Table 31.1. THE TEN COMMANDMENTS FOR COASTAL PROTECTION

1) Thou shalt love thy shore and beach.

2) Thou shalt protect it gainst the evils of erosion.

3) Thou shalt protect it wisely, yea, verily and work with nature.

4) Thou shalt avoid that nature turns its full forte gainst ye.

5) Thou shalt plan carefully in thy own interest and in the interest of thine neighbour.

6) Thou shalt love thy neighbour's beach as thou lovest thine own beach.

7) Thou shalt not steal thy neighbour's property, neither shalt thou cause damage to his property by thine own protection.

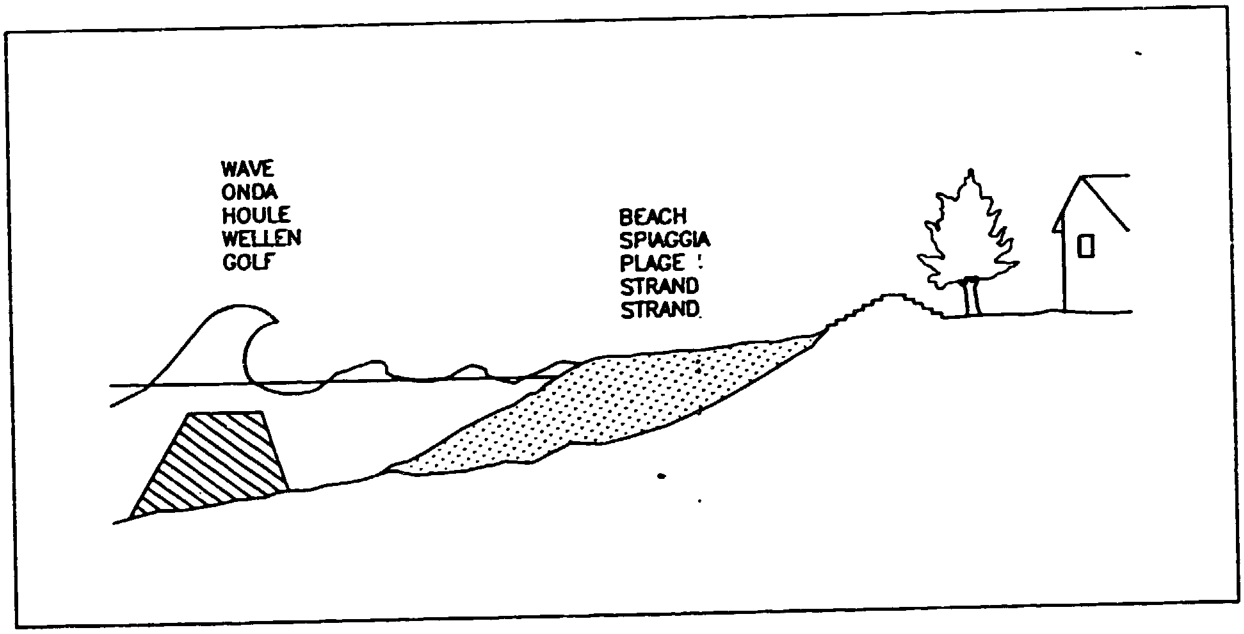
8) Thou shalt do thy planning in cooperation with thy neighbour and he shalt do it in cooperation with his neighbour and thus forth and thus forth. So be it.

9) Thou shalt maintain what thou has built up.

10) Thou shalt show forgiveness for the sins of the past and cover them with sand. So help thee God.

LEOPOLDO FRANCO

COASTAL ENGINEERING GLOSSARY



September 1992

COASTAL ENGINEERING GLOSSARY

by Leopoldo Franco (*)

Introduzione

Il presente glossario riprende un'analoga versione a 4 lingue edita da W.W. Massie della Delft University of Technology (NL) nel Gennaio 1986 integrandola semplicemente con le traduzioni in lingua italiana, senza aggiungere ulteriori termini. Il glossario a 5 lingue permette di tradurre in italiano, francese, tedesco ed olandese i principali termini di lingua inglese riportati in ordine alfabetico.
Sono anche fornite alcune definizioni sintetiche (in inglese) dei vocaboli più specifici dell'ingegneria marittima e costiera.
Il glossario, pur senza pretesa di completezza, costituirà un utile rapido riferimento per studenti ed ingegneri impegnati nel settore emergente della protezione delle coste in una visione moderna sempre più "europea".
Si spera di poter presto integrare il glossario con altri vocaboli ed anche con le traduzioni in danese, greco, spagnolo e portoghese.

Introduction

The following glossary extends an existing 4-language version edited by W.W. Massie of the Delft University of Technology in January 1986, by simply including the Italian translation, without adding new terms.
This glossary makes it possible to translate the terms presented between the five languages, English, Italian, French, German and Dutch.
The table is arranged in alphabetical order in the English language only.
Short definitions (in English only) of some of the more specific terms of coastal engineering have also been added.
The glossary, despite the lack of completeness, can be a useful quick reference for students and engineers involved in the growing field of coastal protection in a modern "EUROPEAN" scenario.
It is hoped to extend the glossary soon with further definition and also with the translations in Danish, Greek, Spanish and Portoguese.

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20133 MILANO, ITALY

English	Definition	Dutch	German	French	Italian
Abstract	1. Short summary with reference listing 2. Difficult to visualize physically	1. Uittreksel, voorlopig rapport 2. Abstract	1. Auszug	1. Extrait, abrégé, résumé 2. Abstrait	1. Estratto, sommario 2. Astratto
Access		Toegang	Zutritt, Zugang	Accès	Accesso
Accretion (= silting up)	Accumulation, build-up of material; opposite of erosion	Aanwas, aanslibbing	Anlandung, Anschwemmung, Anhägerung, Verschlickung	Atterrissement, lais, dépôt, alluvion, envasement	Interrimento, deposito, accumulo
Amplify (to)		versterken	Verstärken	amplifier, survolter répéter, élever, renforcer	Amplificare
Arc		Deel v.e. kegelsnede i.h.b. cirkelboog	Bogen, Kreisbogen	Arc, courbe	Arco
Armor unit	An element of the primary (upper) cover layer of a rubble mound breakwater				Masso, blocco, elemento di mantellata
Articulated platform	Floating structure hinged to an anchor on the sea bottom				Piattaforma articolata
Artificial island		Kunstmatig eiland	Künstliche Insel	Ilot artificiel	Isola artificiale
Bank (= flat)	Shoal area, often isolated at sea	Bank	Plat, bank	Banc	Banco, secca
Bar	Long narrow shoal area	Bank (evenwijdig aan de kust), drempel	Barre, Sandbank	Barre	Barra
Barnacles (= fouling)	Marine shellfish which grow on fixed, hard objects	Eendemossel, aangroeing (schip)	Bodenanwuchs	Filandres	Incrostazione organica
Barrier	A coastal formation resulting from the deposition of material on the edge of a shoal				Barriera, cordone, lido
Bathymetry	Physical configuration of sea bed (see Hydrography)	Dieptelijging	Tiefenmessung, Tiefseemessung, Tiefseelotung	Bathymétrie	Batimetria
Beach		strand	Strand	Plage	Spiaggia
Beach face (= Foreshore)	That portion of a beach exposed to wave uprush	"nat" strand	"nass" Strand	Plage d'estran	Battigia
Beach protection		Strandverdediging	Strandschutz	Protection des plage	Protezione di spiaggia
Beam	1. Maximum width of ship 2. Direction perpendicular to longitudinal centerline of ship				1. Larghezza (di nave) 2. Traverso
Bedload	Material moving along the bottom				
Bedload transport	The quantity of material moved along the bottom with at least intermediate contact Contrast: suspended load transport	Bodemtransport	Geschiebeführung	Charriage de fond	Trasporto di fondo
Bore	A travelling hydraulic jump, sometimes caused by tides in shallow estuaries	Vloedbranding	Flutbrandung	Marée déferlante, mascaret	Mascaretto, onda fluviale di marea
Bottom protection		Bodembescherming	Bodenschutz	Protection du fond	Protezione del fondo

English	Definition	Dutch	German	French	Italian
Boundary condition		Randvoorwaarde	Randbedingung	Condition des limites	Condizione al contorno
Boundary layer		Grenslaag	Grenzschicht	Couche limite	Strato limite
Bow	Forward point of a ship	Boeg, voorsteven	Bug	Prove	Prua
Break (waves)	Loss of stability of wave form, resulting in transformation of energy to noise, turbulence, etc.				Onde frangenti
Breaker zone		Brandingszone	Brandungszone	Zône de brisants, zône de ressac	Zona di frangimento
Breakwater		Golfbreker	Wellenbrecher	Brise-lame	Frangiflutti
Bridge (ship)		Brug	Brücke	Pont	Ponte
Bulk carrier		Bulk carrier	Massengutschiff	Cargo de transport en vrac	Nave rinfusiera
Buoy		Boei	Boje, Barretonne	Bouée	Boa
Buoyancy		Opdrijvend vermogen	Auftrieb, Hubkraft, Schwebefähigkeit	Flottabilité	Galleggiabilità
Bypass		Omloopleiding	Umgehungsleitung	Canal d'évacuation	Bypass, diversivo
Cape (= Headland)	A large scale outcropping of land in the sea	Punt, landhoofd, kop	Vorgebirge, Kap	Pointe, cap	Capo, promontorio
Cavitation	Spontaneous boiling of water, caused by locally low pressures	Cavitatie	Kavitation, Hohlraumbildung	Cavitation	Cavitazione
Celerity	Speed of propagation	Voortplantingssnelheid	Fortpflanzungsgeschwindigkeit	Vitesse de propagation	Celerità
Channel		Geul	Rinne	Chenal	Canale
Chute	A steeply sloping slide, gutter or trough	Steile afvoergoot	Abschüssige Rinne	Radier incliné	Pendio, golp
Clay	Soil particles having a grain size of less than 2 µm	Klei	Ton	Argile	Argilla
Cliff		Klif	Steilküste	Falaise	Falesia
Coast		Kust	Küste	Côte	Costa
Coastal protection		Kustverdediging	Küstenschutz	Protection des côtes	Protezione costiera
Cofferdam		Kofferdam	Kastenfangedamm	Bâtardeau	Gabbione a palancole piatte
Container ship		Container schip	Behälterschiff	Cargo porte-container	Nave portacontenitori
Continental shelf	That portion of the oceans less than 200 m deep	Continentale plat	Festlandsockel, Schelf	Plateau continental	Piattaforma continentale
Cooling water		Koelwater	Kühlwasser	Eau de refroidissement	Acqua di raffreddamento
Coriolis acceleration		Coriolis versnelling	Coriolis Beschleunigung	Accélération de Coriolis	Accelerazione di Coriolis
Current	1. Present 2. Flow velocity	1. Gangbaar 2. Stroming, stroomsnelheid	1. Kurant, gangbar 2. Strömung, Strom	1. Courant 2. Courant	Corrente
Current meter		Stroomsnelheidsmeter	Strommesser	Courantomètre	Correntometro

English	Definition	Dutch	German	French	Italian
Dam		Dalafsluiting	Talsperre	Barrage	Diga
Dead weight tonnage	The carrying capacity of a ship, including fuel and provisions (1 ton = 1016 kg)	Laadvermogen v.e. schip (netto lading incl. brandstofvoorraad en proviand)	Ladevermögen, Schwergutladefähigkeit (effektive Ladung, einschliesslich Bunkervorräte, Ballast und Proviant)	Port et lourd	Dislocamento
Delta	Sediment deposit at a river mouth	Delta	Delta	Delta	Delta
Density current		Dichtheidsstroming	Dichtestrom	Courant de densité	Corrente di densità
Diffraction		Diffractie	Diffraktion	Diffraction	Diffrazione
Diffusion		Diffusie	Diffusion	Diffusion	Diffusione
Dike		Dijk	Deiche	Digue	Argine
Dipper Dredge		Lepelbaggerwerktuig (drijvend)	Löffelbagger	Drague à cuillère	Draga a cucchiaio
Draft (= draught)	Depth of water, necessary to float a ship in still water	Diepgang	Tiefgang	Tirant d'eau	Pescaggio, immersione
Drag (of submerged bodies)		Weerstand (van overstroomde lichamen)	Widerstand (von umströmte Körper)	Résistance à l'écoulement	Trascinamento
Dredge		Baggerwerktuig	Nassbagger	Drague, Dragueur, Excavateur	Draga
Drydock		Droogdok	Trockendock	Cale sèche	Bacino di carenaggio
Ebb	Tidal current flowing toward the sea or the dropping phase of the tide level	Eb	Ebbe	Jusant	Riflusso (marea calante)
Eddy	Turbulence	Neer	Walze, Wirbel	Remole	Vortice, turbolenza
Eddy viscosity	A fictitious viscosity from turbulent energy dissipation	Wervelviskositeit	Wirbelviskosität	Viscosité de foucault	Viscosità turbolenta
Erosion	Removal of material contrast with accretion	Erosie, uitschuring	Erosion	Érosion	Erosione
Fall velocity	The speed at which soil particles settle in still water	Valsnelheid	Fallgeschwindigkeit	Vitesse de chute	Velocità di caduta
Fascine mattress	A bottom scour protection fabricated from willow saplings	Zinkstuk van rijshout	Faschinenpackwerk	Matelas de fascinages	Materassi di fascine
Fender	A device to reduce impact forces between a ship and fixed structures	Fender, wrijfhout, schutplank	Fender, Prellpfahl	Pare-chocs	Parabordo
Fetch	The distance over which the wind blows when generating waves	Strijklengte	Windweg	Fetch	Fetch
Filter		Filter	Filter	Filtre	Filtro
Flood current	Current, directed up the river, caused by the tide	Vloedstroom	Flutstrom	Courant de flot	Corrente di flusso (marea crescente)
Flow pattern		Stroombeeld	Strömungsbild	Champs de courants	Campo di corrente

English	Definition	Dutch	German	French	Italian
Foreshore (= beach-face)	That portion of a beach, which is intermittently covered by water	"nat" strand	"nass" Strand	Plage d'estran	Battigia
Fouling (= barnacles)	Covering of marine growth	Aangroeiing, aanzetting (op schepen)	Bodenanwuchs	Filandres	Incrostazione biologica
Fracture		Breuk, breukvlak	Bruch	Cassure	Frattura
Geostrophic	Caused by earth's rotation				Geostrofico
Grain size distribution		Korrelgrootteverdeling	Korngrössenverteilung	Distribution granulométrique	Granulometria
Groin (= groyne)	A shore protection structure, usually built perpendicular to a coast to retard littoral transport	Strandhoofd (zee), krib (rivier)	Strandbühne	Épis	Pennello
Gravel	Pebbles				Ghiaia
Gust	Short interval of higher than average wind speed	Windstoot	Windstoss	Coup de vent	Raffica
Haul (to)	to pull or tow	slepen, trekken, halen, hijsen	schleppen	trainer, remorquer	Alare, rimorchiare
Headland (= cape)	A major coastal outcropping in the ocean	Punt, landhoofd, kop	Vorgebirge, Kap	Pointe, Cap	Capo, promontorio
Heave	Vertical motion of a floating body	dompen	Heben	Hisser	Sussulto
High water (H.W.)	The instant at which the tide level is highest	Hoogwater (H.W.)	Hoch Wasser (H.W.)	Haute Mer (H.M.)	Alta marea
Hydrography	Study of configuration of sea bed (see bathymetry)				Idrografia (batimetria)
Impact		Botsing, stoot, slag, schok	Stoss	Heurt, choc	Urto
Impeller (pump)	The rotation part of a centrifugal pump	Waaier, schoepenrad	Pumpenflügelrad	Aube, palette	Girante, ventola (di pompa)
Inertia		Traagheid	Trägheit	Inertie	Inerzia
Interface	Surface of separation between two materials having different properties	Grensvlak	Grenzschicht, Übergangsfläche, Grenzfläche	Interface	Interfaccia
Internal wave	A wave propagating along an interface between ocean layers	Interne golf	Interne Welle	Onde interne	Onda interna
Island		Eiland	Insel	Île	Isola
Jet		Straal	Strahl	Jet	Getto
Jetty	A breakwater, groin or crib	Aanlegsteiger	Hafendamm	Jetée	Molo
Ladder	That portion of a dredge structure which supports the soil cutting device	Ladder (waarlangs de emmers worden gehaald)	Baggerleiter	Échelle de drague	Elinda
Lagoon	A shallow area separated from the sea by a barrier	Lagune	Lagune	Lagune	Laguna
Laminar flow		Laminaire stroming	Laminarströmung	Écoulement laminaire	Moto laminare

English	Definition	Dutch	German	French	Italian
Latitude		Breedte (geografisch, astronomisch)	Breite (geografisch), Breitengrad	Latitude	Latitudine
Littoral	Taking place primarily within the breaker zone	Langs de kust	Der Küste entlang	Côtier, littoral	Litoraneo
Low Water (L.W.)	The instant at which the tide level is lowest	Laagwater (L.W.)	Niedrigwasser (N.W.)	Basse Mer (B.M.)	Bassa marea
Mariner		Zeeman, matroos	Matrose	Marin, matelot	Marinaio
Meandering		Meanderen	Mäandern	Méandrer	Meandrizzare
Megaripple	Large ripple on sea bottom, caused by ocean current sediment transport	Megaribbel	Megarippel	Ride géante	Duna gigante
Mole	Breakwater	Havenhoofd	Mole	Môle	Molo, diga frangiflutti
Momentum		Impuls	Impuls, Antrieb	Impulsion	Impulso
Monolith	A single massive unit	Monoliet	Monolith	Monolithe	Monolite
Mud	Loosely packed saturated clay or silt	Modder	Schlamm	Boue	Fango
Navigation		Navigatie, routebepaling	Navigation, Schiffahrtskunde	Navigation	Navigazione
Neap tide	Lowest amplitude tides occurring near the times of 1/4 or 3/4 moon	Doodtij	Nipptide	Morte eau	Marea di quadratura
Nutrient		Voedingsstof	Nährflüssigkeit, Nährstoff	Nutritif	Nutriente
Oblique	Approaching at an angle	schuin, scheef, hellend	Überhangend, geneigt	oblique, incliné	Obliquo
Oceanography	Study of the oceans	Oceanografie	Ozeanografie	Océanographie	Oceanografia
Oil tanker		Olietanker	Öl Tanker	Pétrolier	Petroliera
Peat		Veen, turf	Torf	Tourbe	Torba
Pebbles	Gravel; grains larger than 2 mm.	Kiezel	Kiesel	Galets	Chiaia ciottoli
Peninsula	A spit or pointed headland or cape	Schiereiland, Landtong	Halbinsel	Presqu'île	Penisola
pitch (to)	Rotational motion of a ship about a beam axis	stampen	stampfen	tanguer (tangage)	Beccheggio
Pollution		Verontreiniging	Verunreinigung	Pollution	Inquinamento
Port	1. (Left) 2. Harbor	1. Bakboord 2. Haven	1. Backbord 2. Hafen	1. Bâbord 2. Port	1. Babordo 2. Porto
Potential flow	Flow of an ideal fluid described by specific mathematical equations	Potentiaalstroming	Potentialströmung	Écoulement à potentiel	Flusso a potenziale

English	Definition	Dutch	German	French	Italian
propel (to)		Voortstuwen, voortdrijven, voortbewegen	Antreiben	Propulser	Propulsione
Random	Unpreictable	willekeurig, onvoorspelbaar	beliebig	quelconque	Casuale
Reflection		Terugkaatsing	Reflektion	Réflection	Riflessione
Refraction		Refractie	Refraktion	Réfraction	Rifrazione
retain (to)		keren, behouden	stauen (von wasser), behalten	retenir	Contenere
Retention time	The period during which given water remains in a harbor basin	Verblijftijd	Retentionszeit, Verweilzeit, Rückhaltezeit	Periode de Séjour, de rétention	Tempo di ritenzione
Rigging		Takelage, tuig, vleet	Takelage, Takelung Betakelung	Gréement	Sartiame
Rip current	A local current returning littoral current flow to the sea	Muistroom	Rückstrom	"Rip courant"	Corrente di rip (di ritorno)
Ripple	A wave-like irregularity on the sea bottom	Ribbel	Rippel	Ride	Ondulazione del fondo, duna
River bend		Riverbocht	Flusskurve	Courbe d'un fleuve	Curva fluviale
River mouth		Riviermonding	Flussmündung	Embouchure d'un fleuve	Foce fluviale
Rock		Rots	Felsen	Rocher	Roccia
roll (to)	The rotation motion of a floating about its longitudinal axis	rollen, slingeren	rollen, schlingern	rouler (roulis)	Rollio
Roughness		Ruwheid	Rauhigkeit	Rugosité	Scabrezza
Rubble mound breakwater		Stortstenen golfbreker		Brise-lame et enrochements	Diga frangiflutti a scogliera (o "a gettata")
Rule of thumb		Vuistregel	Faustregel	Règle	Regola empirica
Salinity	Salt content, usually expressed in grams of salt per kilogram of water (parts per thousand)	Zoutgehalte	Salzgehalt	Salinité	Salinità
Salt intrusion		Binnendringen van zout	Eindringen von Salz	Pénétration d'eau salée	Risalita del cuneo salino
Salt water wedge (tongue)		Zouttong	Salzwasserzunge	Coin salé	Cuneo salino
Sand	Soil particles having a grain size ranging between about 2000 um and 50 um	Zand	Sand	Sable	Sabbia
Sand transport		Zandtransport	Förderung von Sand	Transport de sable	Trasporto di sabbia
Scour	Local erosion near some fixed object	Ontgronding	Ausspülung, Auswaschung	Affouillement	Erosione localizzata
Seawall		Strandmuur	Staurwerk	Brise-mer	Muro di sponda, difesa radente
Sedimentation		Sedimentatie, afzetting	Ablagerung	Sédimentation	Sedimentazione
Sediment transport		Sediment transport	Geschiebeführung	Débit solide	Trasporto solido

English	Definition	Dutch	German	French	Italian
Seiche	A standing wave within a confined basin	Seiche	Seiche	Seiche	Sessa
Semi-diurnal	Occurring twice per lunar day	Dubbeldaags			Semidiurno
Semi-submersible	Capable of being partially submerged in order to increase stability and decrease response to waves				Semisommergibile
settle (to)		bezinken, zich afzetten	sich (ab)setzen, sich niederschlagen	se déposer, se précipiter	Depositarsi, precipitare
Set-up	Increase of average water level caused by a. wave action b. wind shear stresses c. barometric pressure changes	Opwaaiing	Aufwehung	"set-up"	Sovralzo
Sewage		Rioolwater	Abwasser	Eaux vannes	Fognatura
Sheet piling		Damwand	Spundwand	Rideau de palplanches	Palancolato
Shelf	Area of the sea adjacent to the coast less than 200 m deep				Piattaforma continentale
Shoal	An area of relatively shallower water	Verondieping, ondiepte	Veruntiefung, Untiefe	Dépprofondissement	Secca, bassofondo
Sidereal day	The time required for the earth to turn 360° on its axis				
Silt	Soil having a grain size ranging between about 50 μm and 2 μm	Slib	Schlick	Vase, silt	Limo
Slack water	The instant at which the (tidal) current is zero	Dood (stil) water, kentering	Stauwasser, Totwasser Stilwasser	Étale	Stanca della marea
Slug	1. A mass of material 2. The unit of mass in the English System of units				
Sluice		Sluis, Uitwateringssluis	Schleuse	Écluse	Chiusa
Spit	A point of land formed from deposited material transported by a littoral current	Spit, Strandhaak	Spitze	Flèche	Freccia, cordone litoraneo
Spring tide	Highest amplitude tides, usually occurring near the times of full and new moon	Springtij	Springflut	Vive eau	Marea sizigiale
Spud	A vertical, retractible pile, used to moor certain types of dredges	Ankerpaal, Stapper		Pieu d'ancrage	Palo d'ancoraggio
Squat	Increase in ship draft caused by its forward motion	Squat, Vertrimming	Fahrtrimm	Déjaugeage	Appoppamento di nave dovuto ad alta velocità
Standing wave		Staande golf, Stationnaire golf	Stehende Welle, Stationäre Welle	Clapotis, Onde Stationnaire	Moto ondoso stazionario
Starboard	Right hand side	Stuurboord	Steuerbord	Tribord	Triborde
Stern	The after (back) end of a ship	Achtersteven	Heck	Poupe	Poppa
Storm surge		Stormvloed	Sturmflut	Onde de tempête, Coupe de mer	Sovralzo di tempesta

English	Definition	Dutch	German	French	Italian
Submergence		Onderdompeling	Eintauchung	Immersion	Immersione
Surf		Branding (van een golf)	Brandung	Déferlement	Frangimento
Surge	1. Longitudinal oscillatory motion of a ship 2. Increase in water level caused, for example, by a storm	1. Schrikken 2. Opstuwing	2. Wanderwelle (mit steiler Front)	2. Intumescence	1.Avanzo 2.Sovralzo
Suspended load	Material in suspension	Zwevend materiaal	Schwebestoff	Sédiments en suspension	Trasporto solido in sospensione
Sway	Beamwise movement of a ship	Verzetten (dwarsverplaatsing v.e. schip	Schwingen		Deriva
Swell		Deining	Dünung	Houle	Onda di mare morto
Tanker		Tanker	Tanker	Pétrolier	Petroliera
Tidal current		Getijstroom	Gezeitenstrom	Courant de marée	Corrente di marea
Tidal prism	The volume of an estuary between the high and low tide levels	Getijvolume, vloedvolume	Tidewassermenge	Volume de flot	Prisma di marea
Tidal wave	1. Long wave of tide 2. (incorrect) name for Tsunami	1. Getijgolf	1. Gezeitwelle	1. Onde de marée	Onda di marea
Tide		Getij	Tide, Gezeit	Marée	Marea
Tide(tidal) range	Elevation difference between high and low water	Getijverschil	Tidenhub	Marnage	Escursione di marea
Tide table		Getijtafel	Gezeitentafel	Annuaire des marées	Tavola di marea
Trade winds		Passaat (wind)	Passatwinden	Vents alizés	Alisei
Trench		Geul, sleuf (van kabels)	Kabelgraben	Tranchée	Trincea, fossa
Tsunami	A long ocean wave caused (for example) by an earthquake	Tsunami	Tsunami	Tsunami	Tsunami
Tugboat		Sleepboot	Schleppschiff	Remorqueur	Rimorchiatore
Turbidity		Troebeling	Trübung	Turbidité	Torbidità
Turbulence		Turbulentie	Turbulenz	Turbulence	Turbolenza
Viscosity		Viscositeit	Viskosität	Viscosité	Viscosità
Vortex		Wervel	Wirbel	Vortex, Tourbillon	Vortice
Warping	Moving of boat by towing from fixed object using a line on a winch				Tonneggio
Water line		Waterlijn	Wasserlinie	Laisse d'eau	Linea d'acqua
Wave attack		Golfaanval	Wellenangriff	Attaque de la houle	Attacco ondoso
Wave climate		Golfklimaat	Wellenklima	Climat d'ondes	Regime ondoso
Wave crest		Golfkam	Wellenkamm	Crête d'une lame	Cresta d'onda

English	Definition	Dutch	German	French	Italian
Wave damping		Golfdemping	Wellendämpfung	Amortissement de la houle, Amortissement des vagues	Smorzamento del moto ondoso
Wave field		Golfveld	Wellenfeld	Champs d'ondes	Campo d'onda
Wave force		Golfkracht	Wellenkraft	Force de la houle, Force des vagues	Forza dell'onda
Wave overtopping		Golfoverslag	Wellenüberschlag	Franchissement de la houle, Franchissement des vagues	Tracimazione ondosa, sormonto
Wave penetration		Golfdoordringing	Wellendurchdringung	Pénétration de la houle	Penetrazione ondos
Wave prediction		Golfvoorspelling	Wellenvoraussage	Prédiction de la houle	Previsione del mot ondoso
Wave theory		Golftheorie	Wellentheorie	Théorie des ondes	Teoria delle onde
Wedge		Wig	Keil	Coin	Cuneo
Winch		Windas, haspel, lier	Winde	Treuil	Argano
Wave run-up		Golfoploop	Wellenauflauf	Montée de la houle, Cote d'affleurement des vagues	Risalita dell'onda
Wave uprush	See wave run-up				
Yaw	Rotation of a ship about its vertical axis	Gieren	Gieren	Embarder	Alambardata

Abstract

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AFTERNOON PROGRAM

1. video presentation about coastal management in The Netherlands with discussion after (stressing on a comparison with the Mediterranean situation)

2. demonstration of geographical information system (GIS) in relation to the management of the Dutch Wadden sea

Geographical

Information

System

(G.I.S.)

- some basics via demonstration

- case: Wadden Sea (shallows / mudflats with tide creeks barrier islands in Northern Netherlands)

G.I.S.

- integral approach for management and planning
- questions for G.I.S.
- principle of G.I.S.
- present use in Holland
- monitoring vegetations
- steps in analyzing
- environmental protection
- technical information
- info-source in Holland

INTEGRAL APPROACH FOR MANAGEMENT AND PLANNING

Recent policy and planning :

more complex and multidisciplinary

Requires: **integral approach**

Basic need for availability, exchange and combination of information from many different sources and disciplines ->

In this respect many possibilities given by G.I.S.

The basic of G.I.S. is the exchange of geographic information.

QUESTIONS FOR G.I.S.

General:

questions which need a combination of information from very different sources.

Examples (recent cases in Holland):

* where are underground pipe-lines, cables, petrol tanks ?

- are there more accidents on roads without lights ?

- are there fields amounting > 30 ha within the planning area ?

* what is the trend in the coast line or in the bank of a river (erosion or accumulation) ?

* where can be sand extraction in a shallow sea which does not influence shipping ways and nature areas ?

- and many, many others

(* concerns coastal management)

PRINCIPLE OF G.I.S.

Integration of unidisciplinary registrations on basis of exchangeable geographic component.

discipline	object	kind of object
water management	canals	lines
,,	groundwater flows	area
,,	lakes	area
,,	sources, wells	point
housing	houses	points
forestry	forests	area
+		
multidisciplinary	integrated maps	

Integrated maps to be used in:
- policy
- planning
- and/or management

PRESENT USE IN HOLLAND

Traffic / transport
- traffic guiding
- road planning
- road maintainance
- road security
- fleet management

Integral management
- sea defence
- river management
- environmental management

Policy / planning
- <u>Planning</u>
  - water purification plants
  - air pollution
  - regional planning
  - transboundary impacts
- <u>Trend analysis</u>
  - coastal regression or transgression
  - urbanization
  - forestry

ORGANISATIONS :
- State department of Planning (RPD)
- State department of water management and roads (RWS) -> origin of demonstration presented
- provincial boards (7 of 12)

MONITORING VEGETATIONS

The State department of water management and roads (RWS) is applying GIS for monitoring the vegetation of:

- all coastal areas
- all areas along main rivers
- wetlands

The frequency of mapping is dependent on the specific dynamics of the area. For example the northern barrier islands are being mapped once per year.

STEPS IN ANALYZING

The RWS-monitoring of vegetations is a landscape-guided vagetation mapping on basis of aerial photographs (false colour).

Steps:

1. systematic photo-interpretation
2. sampling field data. Per character (derived from 1.) 5 plots -> vegetation structure, plant species (abundance)
3. classification of field data
4. second photo-interpretation -> presentation of complexes of plant communities in maps
5. digitalizing of vegetation maps
6. translating into G.I.S.-data
7. applying in management and/or regional planning

ENVIRONMENTAL PROTECTION

Input for G.I.S. can be:

- sources of emission
- monitoring results
- data about natural habitats, human life quality
- distribution models

G.I.S. can be very important for environmental protection because of it's ability to combine and integrate above mentioned environmental and other (economic, social, ...) data at many levels.

TECHNICAL INFORMATION

Present specifications of Dutch G.I.S.-systems

Program ARC/INFO macrolanguage AML

SUN/SPARC station 1 (memory 12 MB internal, 600 MB external)

color monitors S-VGA > 20 "

plotters and laser printers

SUNOS version 4.1 (UNIX)

SUNVIEW

ARC-INFO version 5.01 (January 1992)

Provinces are using Digital VAX or HP workstations

INFO-SOURCE IN HOLLAND

detailed information about Dutch G.I.S. applications can be obtained from:

Rijkswaterstaat

(= State department of water management and roads)

Meetkundige Dienst / RWS

P.O. box 5023

2600 GA Delft

Holland

(address: Kanaalweg 3 b, Delft)

phone no NL/15-691111

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SOME ASPECTS OF THE VENICE LAGOON ECOSYSTEM

Some aspects of the Venice lagoon ecosystem

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Ecotone concept

Since the beginning of this century the ecotone concept has evolved. Clements (1905) considered the ecotone as an area of tension where the most important species of adjacent communities attained their boundaries. Leopold (1933) envisaged the ecotone as a transition zone with a high number of species. The abiotic parameters were not considered by both these definitions.

The successive studies on the ecosystem, considered as a unit separated from the adjacent by well defined boundaries, have neglected these boundaries constituting the ecotones. During the last 20 years the great importance assumed by the ecotone concept was principally emphasized by the following research lines. The studies on the lake eutrophication and acidification, clearly show that the influence of these stresses on the aquatic ecosystem depends on its watershed. As a consequence, the ecotone between the terrestrial and aquatic ecosystem results very important.

Several studies are carried out on the exchange of material and energy across heterogeneous landscapes. Consequently, the ecotone functioning, its resistance to the anthropogenic disturbance, its management and restoration are important subjects for base and applied ecological research.

Now ecotone is considered a transition zone with well defined characteristics, influenced by the adjacent ecosystems, which at their turn are more or less influenced by the ecotone (e.g. Holland, 1988). Estuaries, riparian forests, littoral zone of the lakes, ground water - surface water areas, freshwater and brachish water marshes and lagoons are clear examples of ecotones.

The ecotones play an important role in regulating the material and energy fluxes across two or more ecosystems (Wiens et al. 1985).

Lagoon concept

Lagoon is a typical ecotone forming boundaries between the terrestrial and marine ecosystems. Its salinity is the result of the freshwater load from the land (e.g. rivers, streams, water table) and the sea water load. The ratio between the precipitation and evaporation rate has a relevant influence particularly on the lagoons with a limited exchange with the sea. Lagoon is generally characterized by a high diversity and production. In several cases, because the lagoon is a frail system it may rapidly attain a high eutrophication level if the energy load (e.g. nutrient compounds) is relevant. As a consequence the diversity of the lagoon community decreases and its production increases. The high production per unit surface is the combined effect of the great nutrient load and the contact of the primary production zone, that is the water layer, with the surface sediment (nutrient regeneration zone). The comparatively few species adapted to the modified environmental conditions rapidly grow in number and biomass for the decreased competition with the less resistant species. These surviving species strongly influence the physical and chemical characteristics of the lagoon, which at their turn influence the community.

The lagoon of Venice

Lagoon, on a geological scale, is a temporary ecotone which naturally evolves in a terrestrial or marine ecosystem. The Venice lagoon maintains its identity because of the anthropogenic intervenction which from the XI century is finalized to delay the silting of the lagoon towards a terrestrial environment. The human influence on the water exchange between the sea and the lagoon, the use of the water table and the regulation of the current waters of the watershed have modified the hydrological characteristics of this lagoon and, consequently, its sediment distribution.

The lagoon receives pollutants from various sources; domestic effluents from the Venice city and the human settlements on the lagoon borders, fertilizers and biocides from the agricultural land and toxic load from the industrial area (P.to Marghera).

Except in the area directly influenced by the industrial effluents, the alteration of the ecological characteristics of the lagoon is principally due to the domestic effluents and fertilizers rich in nutrients to the algal growth (Sfriso et al. 1988).

In conclusion, the load due to the man activities, that from natural causes (e.g. leaching, solid material) and the increased hydrological renewal time enhanced the growth of some species and reduced the fitness of others.

Ulva rigida proliferation

The modification of the lagoon system may explain the proliferation of the opportunistic macroalga *Ulva rigida*, Agardh, 1922 (Chlorophyceae) which during the last decades increased its distribution area to the greatest part of the lagoon reaching a biomass value until 15 kg (wet weight)/m^2 (Solazzi et al. 1991). This author estimated for 1987 a mean value of 7.84 kg (ww) m^2 and for 1988, of 3.05 kg. This difference is probably due to the meteorological variations from one year to the other.

Ulva rigida shows two biomass picks; the greatest one in Spring (April - May) and the other, smaller, in Autumn (October). During these proliferation periods the oxygen production, as a photosynthetic by-product, attains saturation values until 300%. Soon after these periods, the decomposition rate of *Ulva* increases releasing into the water the substances incorporated during its span-life. The compounds more resistant to decomposition (e.g; polysaccarides) enrich the sediments of material used by the organisms of the destritus food chain. The oxygen consumption by the aerobic decomposers is the main cause of the anoxic conditions occurring in large areas of the lagoon.

In some zones, during the day the oxygen produced by living *Ulva* is greater than that consumed by the respiration of *Ulva*, heterotrophic bacteria and other organisms of the community. During the night the same zone become anoxic because of the oxygen consumption is not compensated by its production because the photosynthesis is abolished. The anoxic conditions inhibite the activity of the aerobic bacteria and enhance that of the anaerobic ones. As a results the organic substances composing the dead *Ulva* are decomposed and mineralized by aerobic as well as by anaerobic microorganisms.

The fish and invertebrate mass mortality observed in some years is due to the oxygen depletion and, probably, also to some decomposition products released by dead *Ulva*.

From the results of a research carried out in the frame of a contract between UNESCO and University of Venice (Lagoon of Venice ecosystem) it was evident the progressive decrease of the population density of the macrobenthos with the increasing decomposition of *Ulva* . If the anoxic conditions negatively influence a great number of species, some one, such as *Chironomus salinarius*, seem to be not damaged by the oxygen depletion. Indeed, this species can live at very low oxygen concentrations because of the haemoglobine present in its blood and, when the oxygen concentration in the water attains its minimum, *Chironomus* has completed its metamorphosis. This may be the cause of the high population density of this midge at the end of the Summer.

Sulphur cycle

One of the most interesting aspects of the *Ulva* metabolism is the great influence on the sulphur cycle in the Venice Lagoon. According to Show (1985) the sulphur content of the macroalgae varies from 0.5 to 1% on the dry weight and Brault and Briand (1985) have calculated for *Ulva* 4% on the dry weight. A mean value of 5% has been calculated by us for *Ulva rigida* from the Venice Lagoon.

It is probable that a high percentage of the sulphur present in the *Ulva* is tied to polysaccarides. During the *Ulva* decomposition in aerobic medium the sulphur is released and oxygenated to sulphate, under anaerobic conditions the sulphates are reduced to sulphide and sulphur released as H_2S. The latter is a toxic gas (Khan anf Trottier, 1978) that is partly transferred to the air. In some year, such as 1989-1990 the H_2S concentration in the air of Venice was so high to disturb the inhabitants. If the amount of soluble metal compounds are proportional to the H_2S concentration, they precipitates as sulphides. This precipitation eliminating the H_2S from the water column decreases the toxicity hazard to planktonic and necton organisms and increases the metal sulphides in the surface sediments. The H_2S toxicity is related also to the temperature and pH values.

Conclusions

During the last decades the human activities modified the Lagoon of Venice with a consequent elimination or numerical reduction of some species (e.g. Zostera) and the proliferation of other opportunistic species (e.g. *Ulva, Chironomus salinarius*).

Ulva, for its huge biomass and well defined seasonal cycle, exerts a deep influence on the environmental characteristics causing an alternation of periods with high oxygen production and nutrients incorporation by living *Ulva* and periods with great oxygen consumption and release of organic and mineral substances from the decomposing *Ulva* In conclusion, the lagoon of Venice seems to be a system rather stable because of its biological diversity is generally low and the energy flow (e.g. nutrient substances) into the lagoon is great (Odum, 1975). According to Orians (1975) this stability may be called "cyclic".

It is evident that the Ulva proliferation is one of the fundamental problems of the Venice lagoon, due to the modification of the ecotone by human activities. Consequently, during the last years various researches have been carried out on *Ulva* to control its proliferation or, at least, to reduce the effects of its decomposition. Since up today no technique is available to reach these aims, a fraction of the huge biomass is collected during the warm season; for example, in 1987, 10200 tons (wet weight) of *Ulva* have been collected and partly used as fertilizer. Some authors (e.g. Orlandini, 1988 and Missoni and Mazzagardi, 1985) illustrated the possible uses of this macroalga to practical aims.

The research on *Ulva* is important for two practical aims: a) to reduce damages produced by the proliferation but overall by the decomposition of this macroalga and b) to utilize a huge biomass which is renewed every year. The greatest part of the ecological studies carried out in the Lagoon of Venice concern observations in field which aim to the evaluation of the seasonal variations of the *Ulva* biomass. These informations are the basis to estimate the quantitative importance of this macroalga but there is a need of more knowledge on the environmental factors influencing the proliferation and the decomposition of *Ulva* and the effects produced by these processes on the community and the water quality.

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INTERNATIONAL POST-GRADUATE COURSE

IN

HYDROLOGY

INTERNATIONAL CENTRE OF HYDROLOGY "DINO TONINI"

University of Padua - Italy

C O A S T A L

H Y D R O L O G Y

(first part)

by

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1. INTRODUCTION

These lectures are concerned with phenomena in the coastal zone, this is the land area along the coast and the lower reach of the rivers that is directly influenced by the sea and the sea area close to the land. A few more basic subjects like hydraulics, sediment transportation and geology are supposed to be known.

Three coastal formations in the zone where sea and land meet are of special concern to us :

1. Coastal lagoons
2. Estuaries
3. Deltas

The three basic phenomena that determine the form of these coastal formations are :

1. littoral drift by waves
2. tides
3. sediments from the river

They determine to a very large extent what type of coastal formation (lagoon, estuary, delta) will be found.

Why is study of the coastal zone important ?

1. Many people are living there. More than 20% of the world population lives at a distance of less than 50 km from a coast line.
2. The reason for this are the many advantages that the coastal areas have compared to regions further inland. There are also a number of disadvantages, however, which require a careful management of land and water.
3. Estuaries, and even coastal lagoons, may be important sources of water (for domestic and industrial purposes and for irrigation), and they are often used for navigation.
4. Also the groundwater in many coastal areas is of great economic significance.
5. Lately a new phenomenon has come to our attention, namely the probable increase worldwide of the level of the oceans. This will have in the coming century a considerable impact on most coastal areas.

Advantages and disadvantages of coastal regions

Advantages :
1) The biggest discharge of river water mostly occurs near the river mouth. There are however some exceptions (arid zones with a high evaporation and where much water has already been taken out of the river for irrigation purposes).
2) Soils are of recent sedimentary origin and are mostly fertile.
3) River mouths are favourable for water transport and embankments along the river are good for land transport.

Against these advantages there are disadvantages :
1) Pollutants from the whole river basin collect at the mouth, where salts intruding from the sea join them.
2) Coastal regions are liable to floods both from the river and the sea. Expensive flood-protection works will be necessary.
3) Utilization of coastal soils for agriculture requires elaborate drainage works.
4) Traffic across the river mouths depends on costly ferries and/or bridges.

Why should coastal hydrology be studied as a separate subject ?

Coastal hydrology has, compared with general hydrology, the following special features:
1) The flow in the coastal rivers may reverse its direction due to the influence of the tides.
2) Salt and fresh surface and ground waters are simultaneously involved.
3) Sedimentation and sediment transportation are influenced by various factors not found in upland rivers, morphological changes are as a consequence often more pronounced.

2. COASTAL LAGOONS

Wind-generated waves approaching the coast generate transport of sand along the coast (littoral drift), the rate of this transport is a function of the angle between the incoming waves and the coastline and reaches a maximum value for an angle of 50-60°.

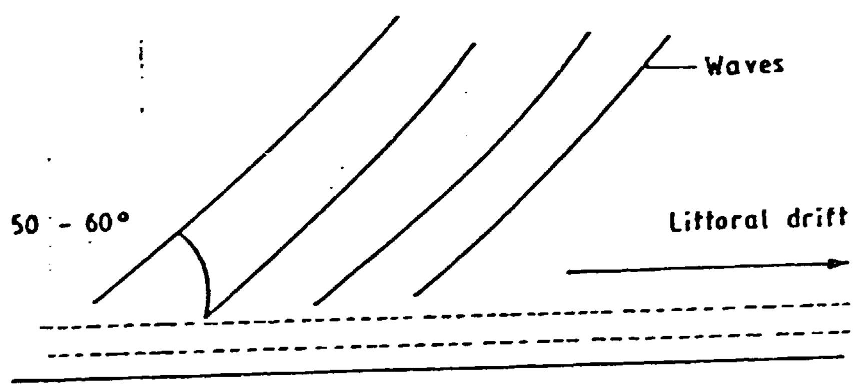


Fig. 1. Littoral drift due to wave action.

If in one season the waves come from one direction and during the next season from another direction the effects on sediment transportation may partially neutralize each other considered over the whole year.

Where there is a discontinuity in the coast line the littoral drift will be locally interrupted and a sand spit may form.

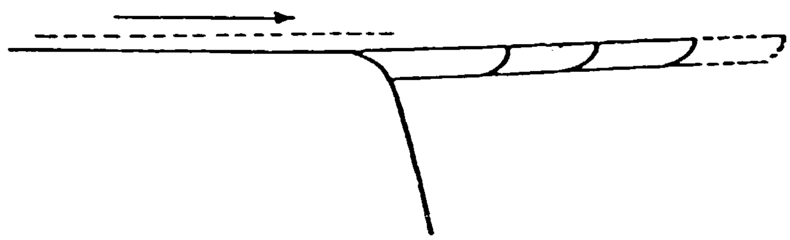


Fig. 2. Development of a spit (sand bar).

A spit will be formed where there is a sufficient quantity of coastal sediments available and where the sediment transportation along the coast mainly occurs in one direction.
By the formation of the spit an enclosed body of water may appear behind the coastal sand bar: this body of water is called a coastal lagoon. Sometimes the lagoon will be entirely separate from the sea and its waters may then become fresh, in other cases there will be one or more openings in the sand bar and the water in the lagoon will remain salty.

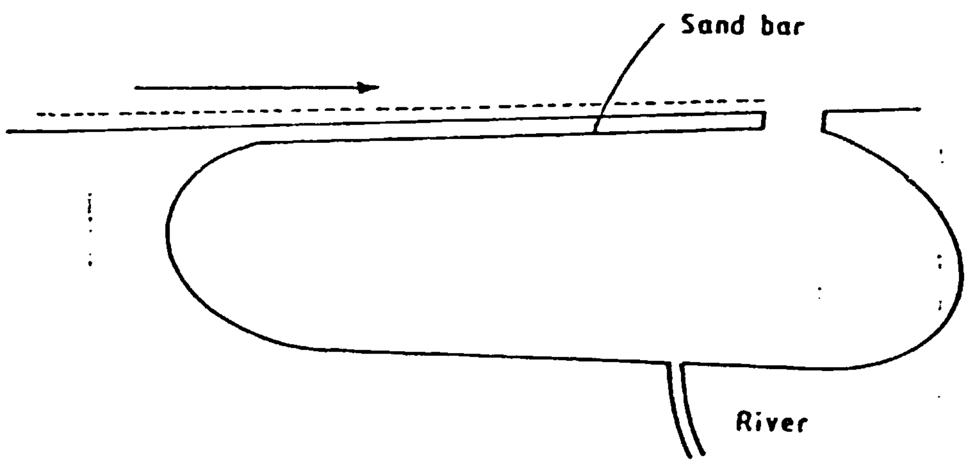


Fig. 3. Formation of a coastal lagoon.

About 13% of the coast lines of the whole world are occupied by lagoons, as for instance almost the whole coast of Western Africa, the east coasts of the USA and Mexico, many coasts in Asia.

If the bar is completely closed the water level in the lagoon will be not the same as the level of the sea. If there is an opening in the bar there is an open connection between the lagoon and the sea. The water level in the lagoon will then follow that of the sea. In a large lagoon tidal currents may occur generated by the tides of the sea.

Often rivers and irrigation outlets will discharge their waters into the lagoon that may become fresh or brackish. In an enclosed lagoon in an arid zone the water can become more saline than that of the sea due to evaporation.

The sandbar (spit) separating the lagoon from the sea is not always stable. Increased coastal currents or a reduction of the quantities of sediments discharged by the rivers into the sea will lead to erosion. As a consequence an opening may appear in the bar, that soon will widen due to the currents. An increase in the quantity of sand carried along by the littoral drift may increase the cross-section of the bar or lead to a natural closure of existing openings. Sometimes such fluctuations have a seasonal character. The sandbar may also be broken by storm waves from the sea or by a flood from inland.

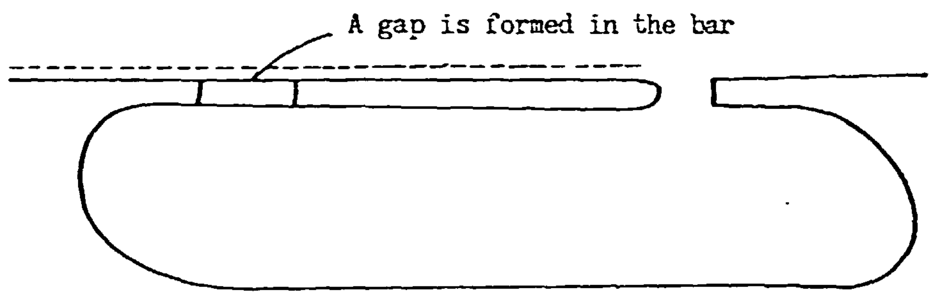


Fig.4. Influence of a storm.

The salinity and other water quality parameters of the lagoon will depend on any connection with the sea, on the discharges coming from inland and on possible human activities (e.g. settlements, industries or fishculture) along the shores of the lagoon.
Due to the littoral drift the position of the opening in the bar may be gradually shifting in the downstream direction.

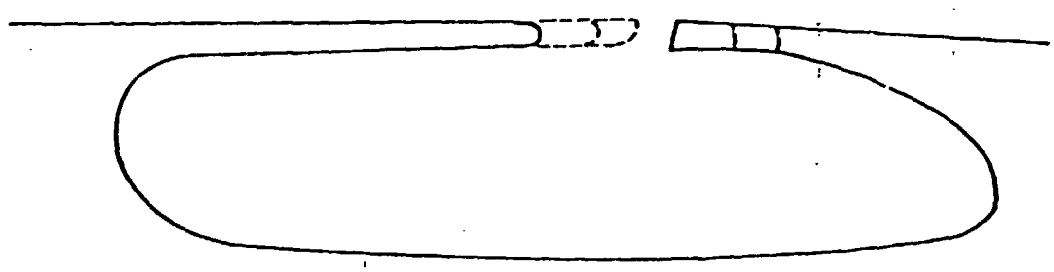


Fig. 5. Shifting of the opening in the bar.

This shifting will diminish possibilities for using the coastal bar for tourism, e.g. hotels, bungalows and sports facilities. Keeping the opening in place by engineering works is not an easy task and will mostly be very expensive.
Behind an opening in the bar the current will scour out, often deep, gullies in the lagoon. Coastal lagoons may also become shallower and may even get partially filled up by natural or man-made causes.

Deposition of sediments from rivers,
Precipitation of silt particles due to saline or acid waters,
Fixation of sediments by plants and animals,
Growth and decay of reeds, rushes and other water plants,
sometimes followed by the formation of peat.
Among the man-made causes for the reduction of the volume of a lagoon can be mentioned:
Reclamation of areas for traffic (roads, ports, airports), housing or industry,
The arrangement of beds for the culture of oysters and shrimp, and the building of fishponds and salt pans,
Siltation due to the discharge of sewer water or of the effluent of waste-water treatment plants.

Some coastal lagoons have a typical form. An example is the kind of lagoon that is sometimes formed between an island or other object and the shore. Under certain circumstances a spit will develop connecting the island with the shore. Where two such spits develop a lagoon will be formed. This coastal form is called a tombolo.

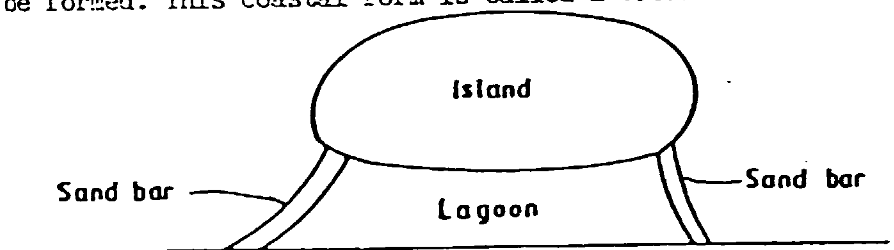


Fig. 6. Formation of a tombolo with two sand bars.

There are many, often conflicting, options for the management of a coastal lagoon. A careful planning is therefore essential. This is illustrated by the following example :
The Tak Bai lagoon situated in Thailand, just north of the frontier with Malaysia at the eastern coast. A river forms the boundary. Its mouth is connected to the lagoon by a short channel. If the bar is in place the water in the lagoon becomes brackish by the inflow of river water. In the storm season the bar is often breached and then it will remain so for a longer time until the littoral drift has brought enough sand to close it again. With an open lagoon sea water enters freely and also fishes using the lagoon as a spawning ground. If the lagoon is closed its salt content gradually decreases and marine species of fish may die.

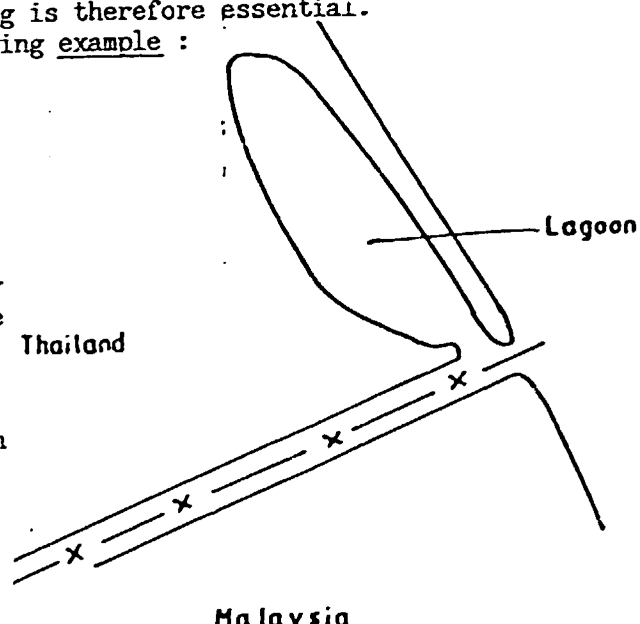


Fig. 7 Lagoon of Tak Bai, Thailand.

At the landside of the lagoon there are peatsoils, there are plans to reclaim them for agriculture. This drainage water is acid, however. Discharging it into the lagoon will harm fishlife. Obviously maintaining an appropriate water quality will be the major concern for the management of the lagoon.
Management options are: a. Keep bar open so that there is a free contact between lagoon and sea and promote artisanal fisheries by the local population. In addition part of the lagoon can still be used then for the culture of fish (red snapper) and prawns. A good water quality will require then that a boundary canal be made to discharge the drainage water directly to the sea. b. Keep the bar closed and maintain the right water quality in selected basins within the lagoon by pumping. Culture of fish and prawns on an industrial scale will be possible then, but the chances for the population for artisanal fisheries will be unfavourable.
How to keep the coastal bar stable and the entrance open? Building breakwaters is very expensive. In this particular case purchasing a small suction dredger that periodically keeps the opening in shape showed to be the most economic solution.

The Tak-Bai case shows clearly that managing a coastal area involves many different considerations and not only hydrology or hydraulic engineering. Objectives should first be defined and priorities set. Various options should be studied, also taking into account environmental interests.

3. DELTAS

There are many deltas in the world. They belong to the most fertile areas with the biggest population density.

How does a delta develop ?
Consider the mouth of a river. Assume for the moment that the level of the sea is constant. The sediments carried by the river will settle to the bottom as soon as the river enters the sea and the water velocity is reduced. Fine particles will in addition settle as soon as the river water mixes with the salt water of the sea.

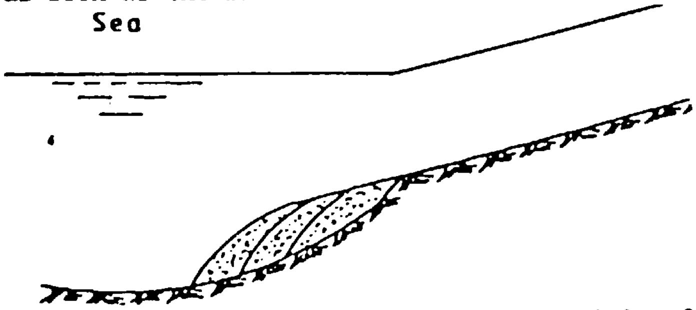


Fig. 8. River flows into the sea, depositing forebanks.

The river deposits settling to the sea bottom form so-called forebanks.

This material is in the beginning not yet very well consolidated. There is now a new boundary between river and sea. The river is now as it were longer. As the sea level remains the same, this will result in a decrease of the slope of the river and more materials will settle to the bottom.

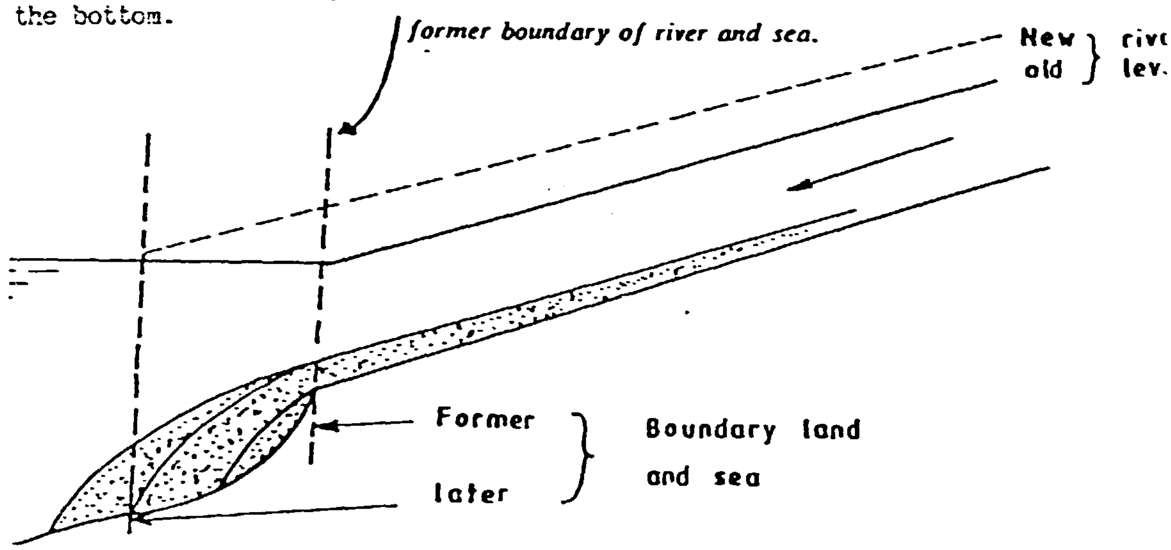


Fig. 9. Shifting of the boundary between river mouth and sea.

The cross-section over the river will get the following shape:
The river bed has risen due to the sedimentation after the river slope has decreased. Also the water level will have gone up. In periods that the river flows more than bankful, its levees will be flooded. Coarser sediments settle on the banks close to the river and the levees grow in height. Finer materials will settle in the areas behind the levees and form impermeable, so called basin soils.
The areas behind the levees are swamps, which need to be drained first. Levees are good for horticulture and fruit trees but are also nice for dwelling and can also be used for traffic (roads). So there is a potential conflict of interests. The basin soils, on the other hand require high investments before they can be intensively used. Sometimes they serve as nature reserves.

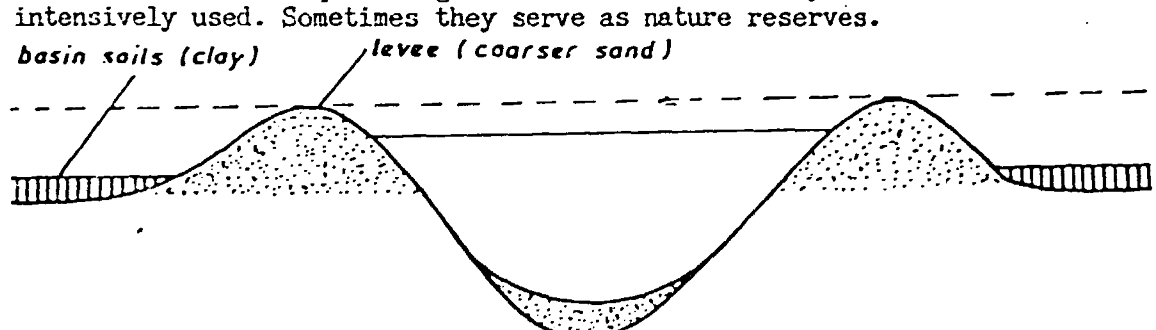


Fig. 10. Formation of natural levees and basin soils.

The gradation (sorting out) of sediment also takes place along the riverbed. The coarser materials settle more upstream and the finer sediments more downstream.

During a flood a levee may break and the water may find a shorter route to the sea (fig. 11). The river may in this way branch-off repeatedly a delta will begin to be formed.

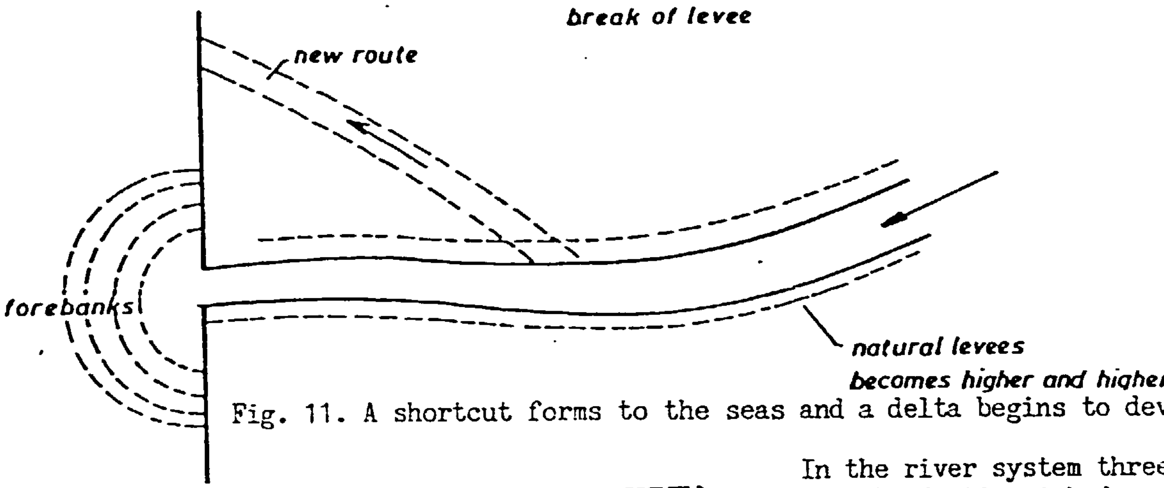


Fig. 11. A shortcut forms to the seas and a delta begins to develop.

In the river system three areas can be distinguished:

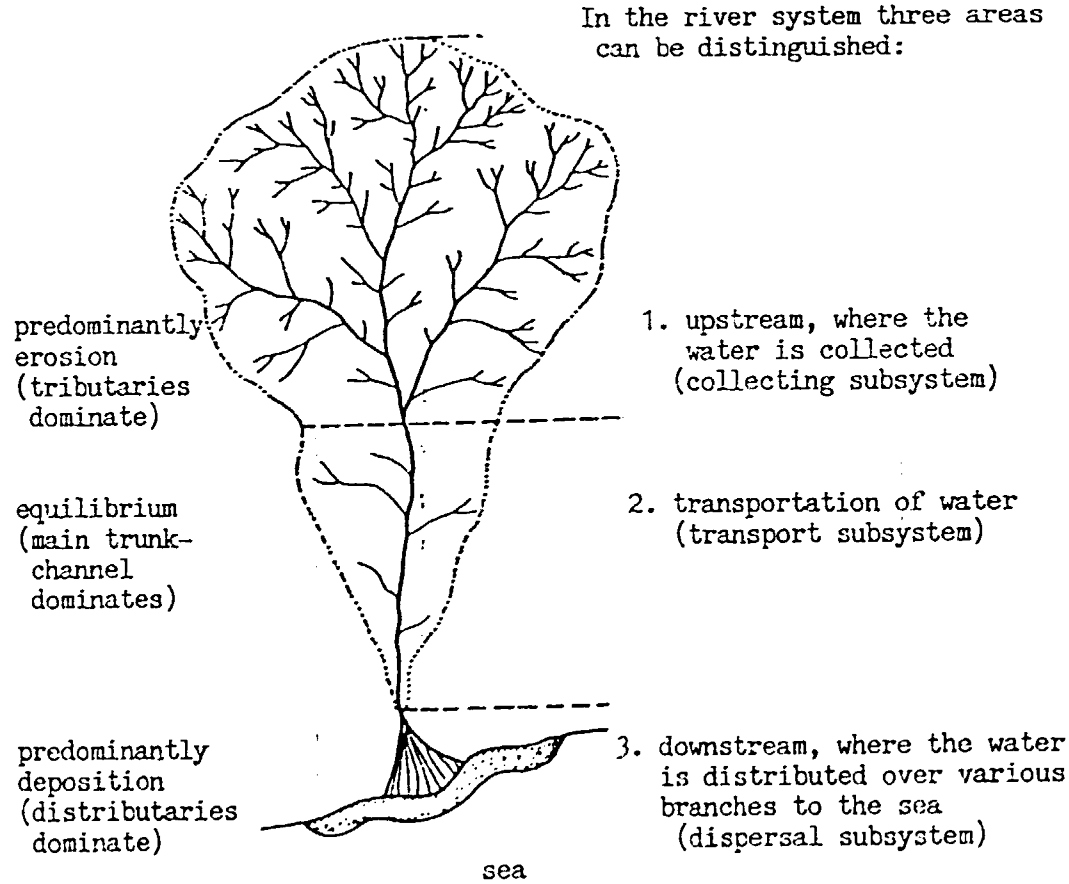


Fig. 12. Idealized diagram showing the major parts of a river system.

The boundaries between the three areas are not always clear.

Deltas occur in a big variety of shapes. Why ?
This is due to differences in the relative importance of the three main factors determining coastal sedimentation, namely: river sediments, tides and littoral drift. One can classify deltas accordingly.

It has been proposed to clarify the classification of deltas by representing the relative influences of these three factors in a ternary diagram (fig. 13).

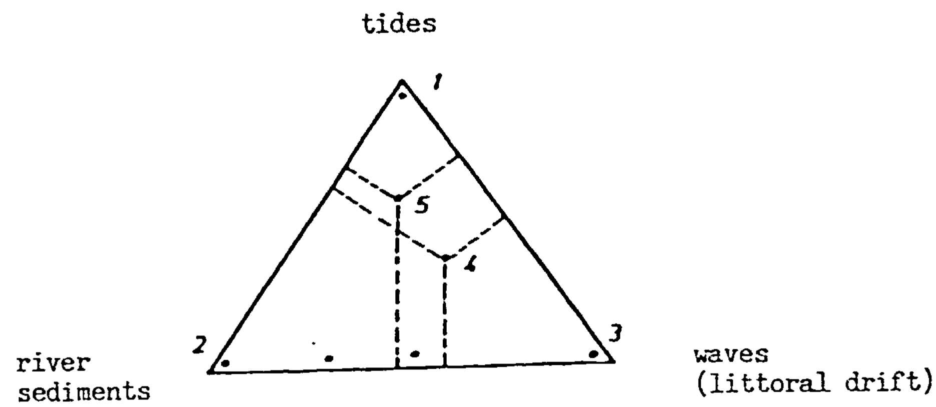


Fig. 13. Delta classification in a ternary diagram.

This diagram only gives a general indication.
A few deltas in the world are almost entirely shaped by the tides, these deltas belong in the vertex of the triangle, examples are the Fly River in the South-West of Papua New Guinea and the Bramaputra river in Bangladesh (1). The banks in the mouth of the Fly River follow all the direction of the tides.
In other deltas tides hardly play a role nor do the waves; the river sediments are predominant, this type of delta belongs in the left bottom angle (2), e.g. the River Mississippi.
A river mouth with a lagoon (spit), where the littoral drift is predominant belongs in the right bottom angle (3).
Many deltas in the world belong close to the base of the triangle (between 2 and 3), here the tides do not play a major role but river sediments and littoral drift are important (e.g. the deltas along the Mediterranean Sea).
It is a very good exercise to try to locate a given delta into the diagram, because it gives an insight into the character of a delta.

The level of a low-land river with its embankments is above the surrounding area.
The consequences are:
1. Seepage through the natural levees, which consist of coarse material.
2. The precipitation from the surrounding areas cannot drain away directly towards the river.

In many delta areas secondary rivers have developed parallel to the main stream which collect this seepage water and the drainage water from the surroundings and drain this directly to the sea (Fig. 14)

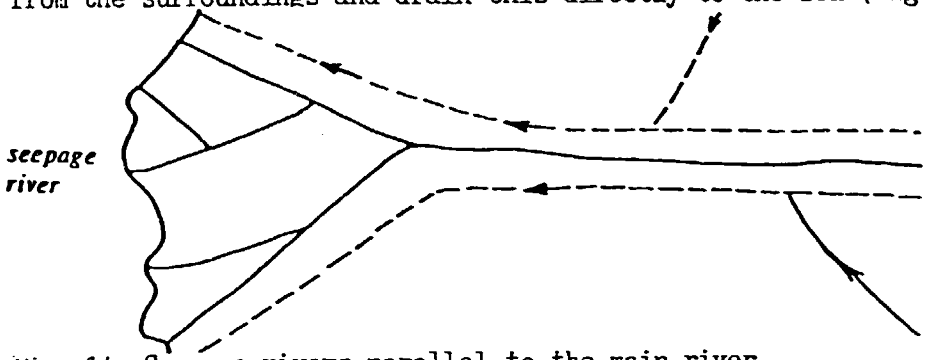


Fig. 14. Seepage rivers parallel to the main river.

A well-known example is the lower part of the River Mississippi and its parallel river the River Atalaya (Fig. 15).

Fig. 15. Lower Mississippi river and Atalaya seepage river.

4. SEA-LEVEL VARIATIONS

a. Average sea level

Determining the mean sea level is not always an easy task.
A longer period of observation will be required to get sufficient data to calculate the average sea level. There are in many places still fluctuations with a period of up to 18.3 years. For most practical purposes an observation period of six months will be satisfactory, however, to obtain the average long-term sea level.

b. Short-term variations in sea level

The friction of the prevailing winds moving over the surface of the sea causes a slope of this surface (Fig. 16)

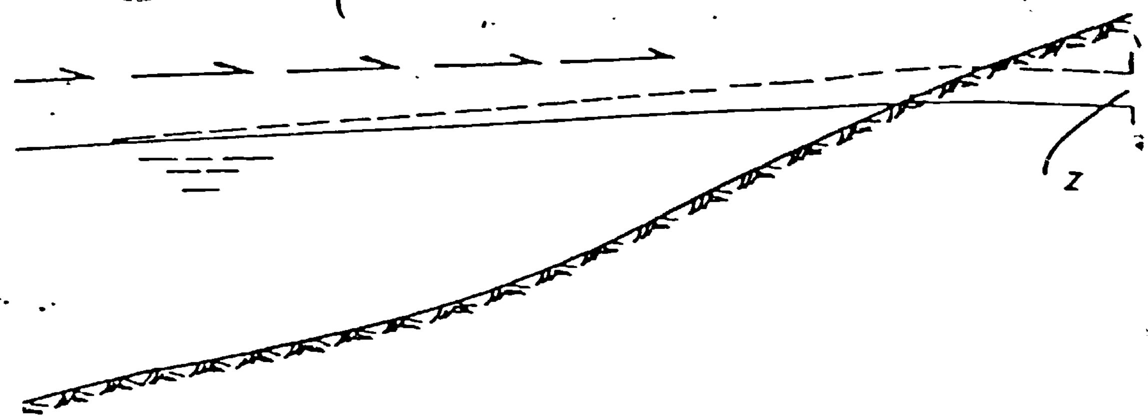


Fig. 16. Wind friction on the sea surface.

If the wind blows long enough into the same direction this so-called wind set-up becomes of importance.

It can be calculated by the following formula:

$$z = 3.6 \times 10^{-7} \frac{w^2}{h} \cdot L$$, in which:

z = wind set-up (in m)

w = wind speed (in m . sec-1) measured at 6 m above sea level (= height of the bridge of a ship)

h = water depth (in m)

L = length over which wind blows effectively, the fetch (in m)

This formula is only valid if z is much smaller than h.
As h is in the denominator there will be only a small wind set-up where the water is deep.

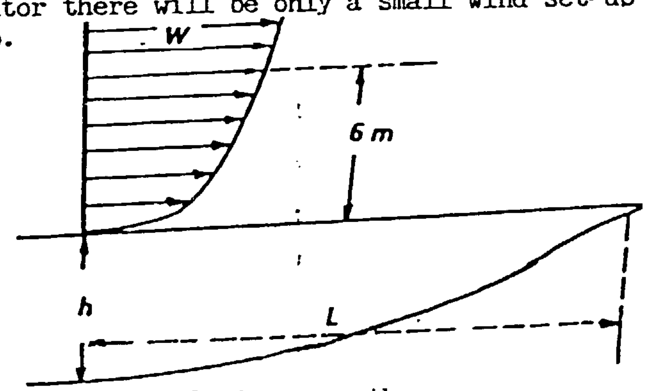


Fig. 17. Velocity profile of wind blowing over the sea.

In some instances this wind set-up can be very high, a classical example is the northern shore of the Gulf of Bengal, where z can reach up to 6 to 9 m.

In some parts of the tropics winds occur with a very high speed, and consequently the wind set-up can become there quite important. Fortunately, in the tropics these heavy storms will as a rule not last very long. In the temperate zones maximum wind speeds are less, but they will last longer.

c. <u>Long-term variations in sea-level</u> :

The level of the sea has constantly been changing with respect to the level of the land during the history of our planet. In some eras the sea level increased (or the land level went down), in other eras the sea level decreased (or the land level went up).

The main causes are :
1. Changes in the proportion of the world's waters that are stored in the form of ice. Changes in the sun's radiation and the temperature of the atmosphere determine this.
2. Tectonic movements, either :
   a. over large areas (plate tectonics), or
   b. more locally (land subsidence, to be discussed later).

Since the latest glacial period (round 18.000 years ago) the temperature of the atmosphere has been increasing very gradually (but not continuously), ice masses melted and the level of the oceans increased. The natural systems of coasts and rivers continuously adapted to these gradual changes and also man could adapt his way of life to these changes. The worldwide average rate of increase in sea level has been round 8 cm per century during the last 1000 years.

d. <u>Expected increase in the rate of sea-level rise due to changing environmental conditions</u>.

Most probably this rate of the rise of sea level has increased over the last 100 years and it is likely that it will still further increase during the coming century.
These changes are caused by the activities of man.

The atmosphere of the earth consists of a mixture of gases, mainly nitrogen, oxygen, and argon. There are in addition a number of trace gases of which carbon dioxide has a special importance. In geological history the quantities of these atmospheric gases have not always been the same. Much of the originally available carbon dioxide has been bound in the earth's crust in the form of carbonate rocks or of fossile organic carbon (peat, brown-coal, oil, natural gas). Since 1860 man is recovering this organic matter on an industrial scale in order to burn it for power generation, locomotion (motorcars) and industrial processes.
The consequence is that the amount of carbon dioxide in the atmosphere has increased considerably, from 275 ppm in 1870 to 350 ppm in 1989. (1 ppm = 1 part per million = 1 milliliter per cubic meter).

The earth gets its energy from the sun in the form of radiation. Most of this radiation is reflected back into space. Thanks to the presence of carbon dioxide and some other gases part of this radiation remains in the atmosphere, without this phenomenon the surface of the earth would be a very cold place. There exists consequently a heat equilibrium that keeps the earth inhabitable for man.

By the increase in the contents of carbon dioxide in the atmosphere and by the presence of other gases and particles introduced by man into the atmosphere, the reflection of the sun's radiation has gradually been decreasing and the earth is slightly, but constantly, warming up. This increase in temperature amounted in the past 100 years to round 0.6° C. In the tropics this warming up is slightly less pronounced, closer to the poles it is bigger.

Maintaining the level of welfare of the population of the earth and extending it to the less-privileged nations will require (with the present state of our technology) a continuing consumption of fossil fuels and a continuation of the industrial processes that have an impact on the atmosphere.
In the next 100 years the carbon dioxide contents of the atmosphere is therefore likely to double, and the temperature would be raised then by 3° - 5° C. Even if the consumption of fossil fuels would stop now, these effects will continue for a long time.

This increase in the temperature of the atmosphere has in the following ways an impact on the level of the sea :
a. Thermal expansion of sea water
b. Melting of glaciers and of permafrost
c. Changes at the poles.

a. The expansion of seawater is not the same for all temperatures. A layer of 100 m of seawater of 25° C expands 3 cm per ° C. For a water temperature of 5° C this expansion is much smaller, about 1 cm per ° C. In an ocean with a depth of 4000 m, the waterlevel will then go up by up to 1.2 m for each ° C warming up.

Studies are being undertaken on the rate at which this is happening. The upper 200 m of the oceans are well-mixed by waves and changes in the air temperature will quickly be transferred to the water in this zone. Convection to deeper layers goes slower. Studies on mathematical models indicate that by the year 2050 the sea-level will have risen due to thermal expansion by round 0.2 m.

b. Melting of glaciers
The retreat of glaciers in Europe and North-America has been well studied in detail. On other regions, such as the Himalayas, China, the Andes, less is known, but the melting of glaciers seems to be a process that is occurring worldwide.
Also the rocks around the glaciers are heated by the surrounding air and this heat adds to the melting of the glacier.
Permafrost in Siberia and Alaska will also be reduced in extent.
One estimates that the melting of glaciers and permafrost will result in a further increase of the sea level of 0.1 m till the year 2050.

c. Changes at the poles
The Arctic (North pole region) consists of a huge floating ice field. If floating ice melts the level of the water will not change (Archimedes' law).

The Antarctic (South pole region) consists mainly of a continent covered by a thick layer of landice. The ambient temperature is so low that a small increase in air temperature will not cause an appreciable melting of ice.
The increase in the temperature of the sea water combined with the increase in sea level presents a real danger for the equilibrium of the ice round Antarctica.

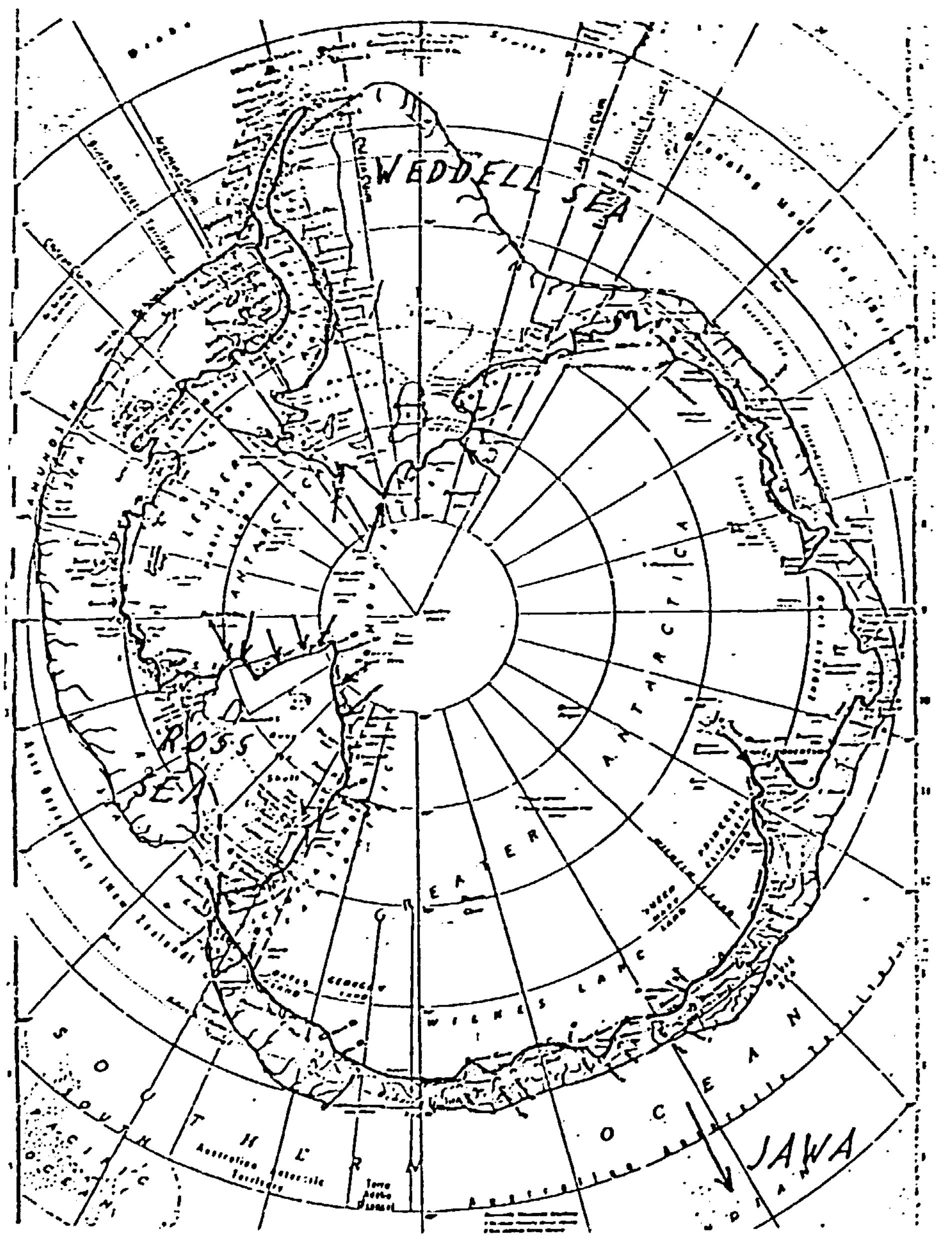


Fig. 18. Antarctica.

The two border seas of the Antarctic, the Ross Sea and the Weddell Sea are covered by ice sheets that are fed by huge ice streams flowing from the interior of the continent. The toes of these ice streams are supported by the ice sheets on these seas. (Fig. 18)
These ice sheets are not fully floating as they are resting on natural sills at the entrance to each sea. A slight increase in temperature and level of the ocean may lift these ice sheets somewhat and initiate their disintegration. This would lead to a rapid sliding down of the ice masses from the interior. This ice would then drift into the ocean to melt there, causing a rapid sea-level rise of 1 m in 70 years or 4.5 m in 150 years.

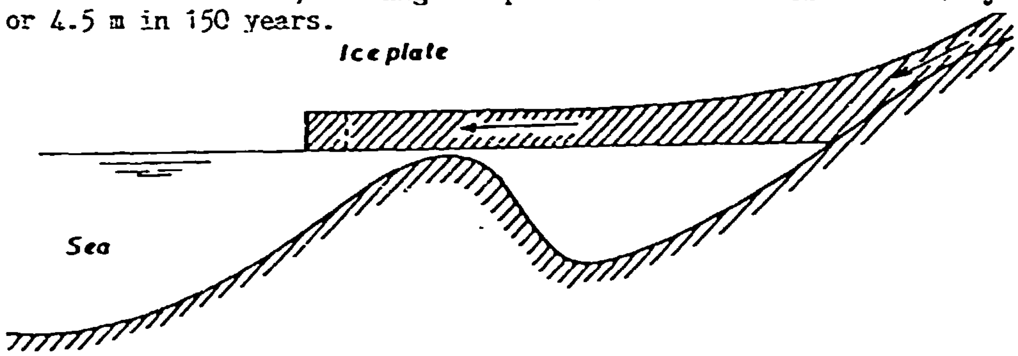


Fig. 19. Sills at entrance of Ross Sea and Weddell Sea.

An increase in sea level of 0.30 to 0.50 m by the year 2050 would cause important changes at our coastlines and would require important adaptations. An increase of 1.30 - 1.50 m in this short time span, as can be expected after a break down of the ice masses in the Antarctic border seas, would be catastrophic for low-lying areas.

Coastal erosion would increase. Especially many tropical areas would be seriously affected. The natural building-up of embankments by siltation would no more keep pace with the increase in the level of the sea. Mangrove areas and coral reefs would no more be able to build themselves up.

In many places there will be a severe coast erosion. Land areas will be flooded. Dikes and weirs will have to be heightened. Drainage by gravity will no more be possible and pumping stations will have to be built.

Mangrove forests may partially adapt. Pollution might damage them, however, as well as ill-planned reclamation. The same is true for coral reefs. A well-planned coastal management is more essential than ever, taking a possible rise of sea level well into account.

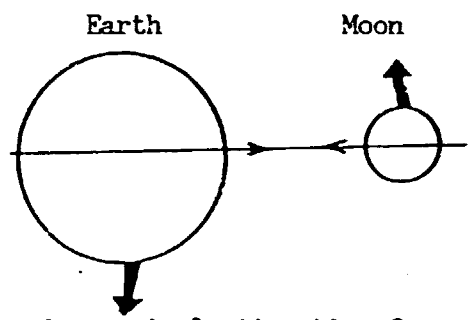
A rapid rise of sea level will also have serious political consequences. The industrialized countries could only reach their actual state of prosperity by the use of fossil fuels. Many countries that suffer now from these consequences are living in a state of relative poverty. Should these poorer countries pay the bill for coastal management works which are needed because the rich caused the sea level to rise ?

5. TIDES OF THE OCEANS

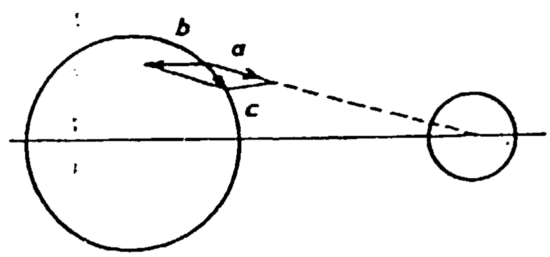
On the beach one can observe :
- Wind waves;
- Swell (with a length of a few hundred meters);
- Tidal waves (with a period of round half a day).

Tides are caused by the attraction by celestial bodies, specifically the sun and the moon. The attraction by the moon is the most important one; the influence of the sun = 0.46 the influence of the moon.

a. Influence of the moon



There is a mutual attracting force between the earth and the moon. They do not clinch together, because of centrifugal forces due to their rotation. There is an equilbrium between the gravitational and the centrifugal forces for the earth as a whole. These forces also act, however, on each individual particle of these bodies. Loose particles, like water and air, can hence move independently with respect to the earth as a whole.

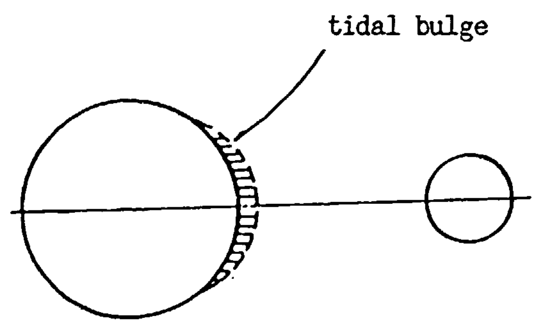


a : attraction force

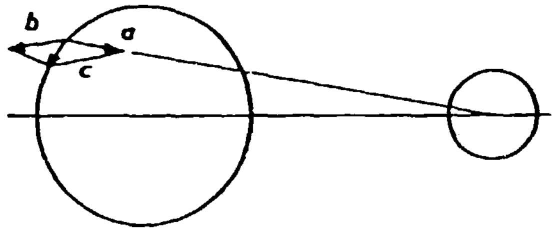
b : centrifugal force

c : resultant force

The water tends to flow towards the side where the moon is located. This results in a tidal bulge :



On the other side of the earth the following happens:



a : attraction force

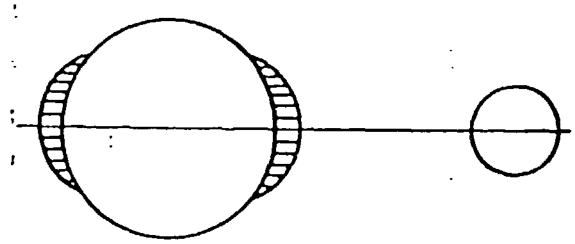
b : centrifugal force

c : resultant force

Here there is a somewhat smaller attraction force from the moon (larger distance), whereas the centrifugal acceleration is somewhat higher than for the earth as a whole. The water tends to flow now to the side opposite of the moon.
So there are two tidal bulges: one at each side of the earth.

An observer at a fixed point on the shore of the ocean sees in a day:
1. a zone of high water passing,
2. a zone of low water passing,
3. a zone of high water again, followed by
4. a zone of low water.

There is actually a water wave, the tidal wave. During the 24 hours of one earth rotation the moon has advanced to a new position. Our observer will meet the moon again after an additional 50.47 min. Therefore the exact time of recurrence of this phenomena is 24 hours and 50.47 minutes. Within this time our observer sees two successive waves passing, so the period of each tidal wave (due to the moon) is 12 hours 25.23 minutes.



Now let us check whether this tidal wave is a long period wave:
(A long period wave is characterized by a wave length which is considerably longer than the water depth.)
Take an ocean with a depth = 4000 m.
Now the wave celerity:

$c = \sqrt{g \cdot h} = \sqrt{10 * 4000} = 200$ m/sec

The wave length :

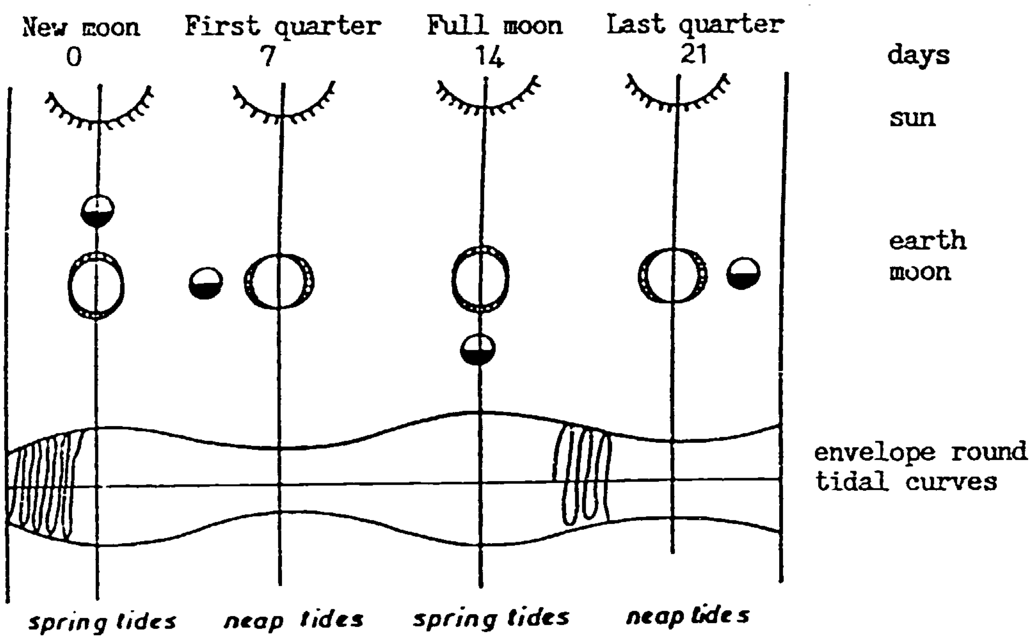
$L = c * T = 200 * 12\text{hr } 25\text{min} = 200 \text{ m/sec} * 45\,000 \text{ sec} = 9000$ km

As L is considerably longer than the waterdepth, this tidal wave can definitely be considered as a long wave (9000 km is about one quarter of the circumference of the earth).

2. Combined influence of moon and sun.

The attracting force from the sun is about half of that from the moon. Their combination gives:

Four basic positions of sun, earth and moon :



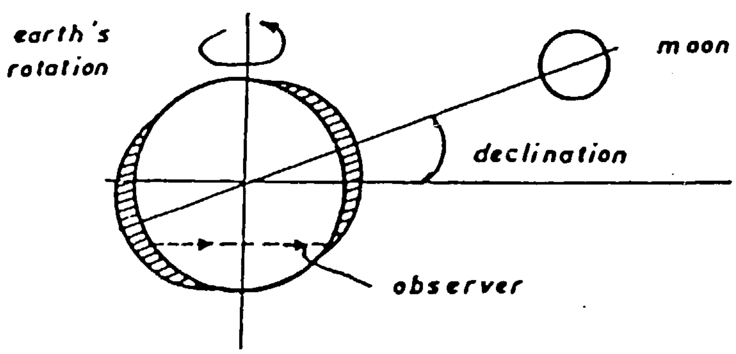
Spring tides occur on days 0, 14 and 28, they are characterized by more pronounced water levels:

- the high tides are extra high;
- the low tides are extra low.

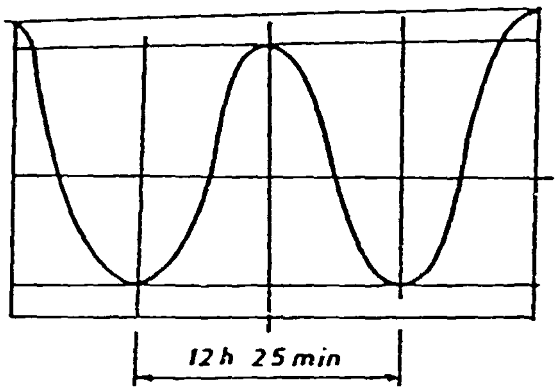
On days 7 and 21 neap tides occur, high and low tides are less pronounced.

3. Declination of the moon.

The moon is not rotating in exactly the same plane as the earth. This phenomenon causes the declination of the moon.



In one day the observer on earth still sees two times high water and two times low water passing. But the waterlevels of the two high tides are for him not equal. He observes one time a somewhat higher high tide and one time a somewhat lower high tide. So within 24 hr and 50 min there is the following picture.



This phenomenon, due to the declination of the moon, is called the daily inequality. As the declination of the moon varies between + 28° and - 28°, the daily inequality varies over a month.

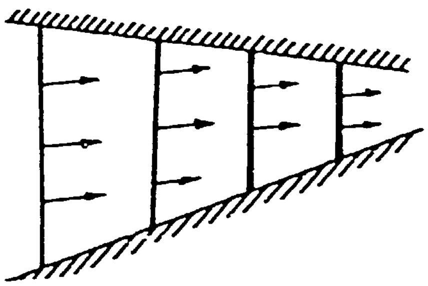
4. Height of the tides.

The masses and relative distances of sun, moon and earth are known. So the forces working on the water masses at the surface of the earth can be calculated and with that various tidal parameters, like the amplitude of the tide. The tidal height in the open ocean obtained in this way has an order of magnitude of only a few decimeters. Really observed tides are higher for most places in the oceans.

The reason for these higher tides is the following:
The oceans south of the continents (South-America, Africa and Australia) form one continuous channel, where a tidal wave can freely progress. The speed of a long wave in this channel corresponds to the apparent speed of a point on the rotating earth under the moon, hence the tidal force moves over the surface of the earth with the same velocity as a long period wave; in this channel the tidal wave is in resonance with the tide-generating force. According to this theory the tides are mainly generated in this channel round the southern hemisphere. Tidal waves generated there enter the oceans (Indian, Pacific and Atlantic), running north.

5. Heights of the tides at specific locations.

The tidal waves running in northern direction through the oceans meet obstacles (shores and shoals), which influence the height of the tidal wave. Reflection of a tidal wave results in a returning wave with different height. A wave entering a funnel-shaped channel may increase in height by concentration of the wave energy over a smaller width.



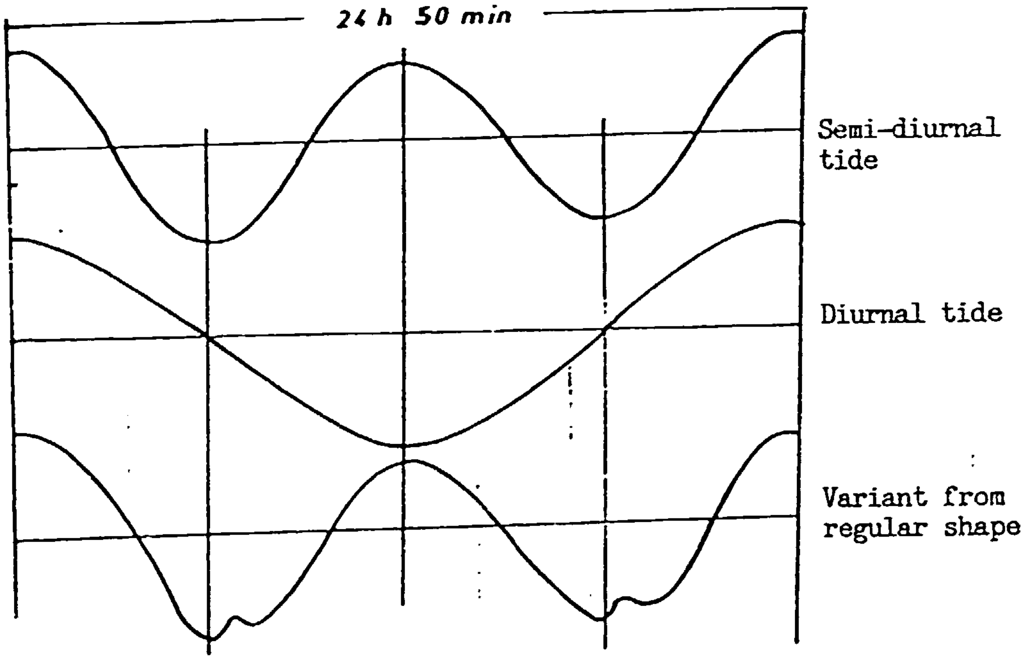
Friction in shallower waters may, on the other hand, reduce the height of the tide.

In case tidal waves meet after having traveled by different routes around islands, their superposition may either result in higher or in lower tides depending on the phase differences between these waves. Also the shape of the wave may have changed then.

In a few places on earth very high tides occur (as e.g. in a part of Fundy Bay, Canada (till 16 m), and at the west coast of Korea).

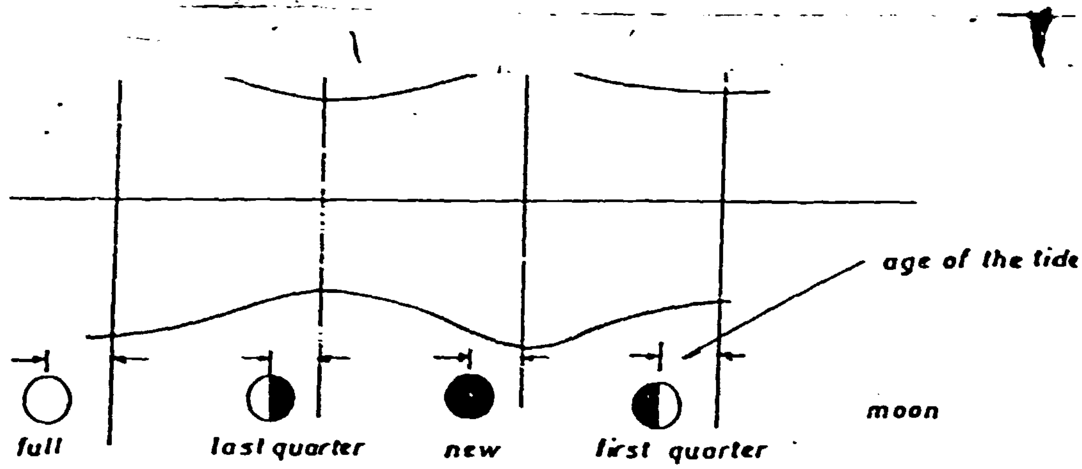
6. Diurnal, semi-diurnal and mixed tides.

A semi-diurnal tide occurs twice a day, a diurnal tide only once. Variations in shape may occur locally. Mixed tides are during part of the month diurnal, part of the month semi-diurnal.



7. Age of the tide.

Superposition of the waves due to sun and moon gives per (moon)month (28 days) two spring tides and two neap tides. Spring tides occur some time after new and full moon; neap tides occur some time after the first and last quarters.

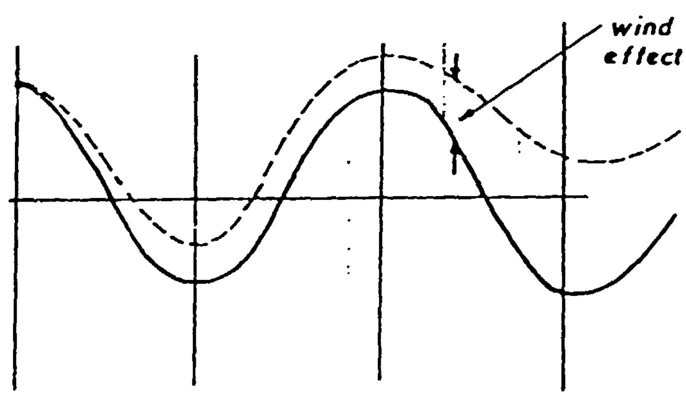


These time lags can be explained by the time necessary for the tidal wave to travel from the channel round the southern hemisphere to the place under consideration. This so-called age of the tide for a given location makes it possible to predict the times of high and low waters at a certain hour on a certain date.

8. Prediction of the tides.

One can predict the height of the tide at a certain place and time from tables published periodically by agencies concerned. If no tide table exists for a certain location and there is a port nearby one can consult the tide table for that port and possibly extrapolate. Otherwise one can measure the tides at a certain location during a period of a few months and analyse these data in order to obtain a set of parameters. These tide parameters together with astronomical tables make it possible to calculate the tides for that location at a given date. Computer programmes exist to execute this calculation.

Monsoon winds or storm surges will cause the water levels to differ from predicted tides. In general wind effects must be superimposed on the astronomical tides.

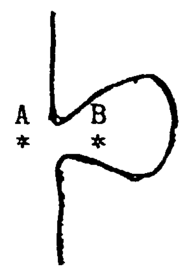


9. Tsunami

After an underseas eruption or land slide, very long waves may occur, which possess much energy and can be very destructive. Although for these so-called tsunamis sometimes the term "tidal waves" is used, they are not related to the astronomical tides.

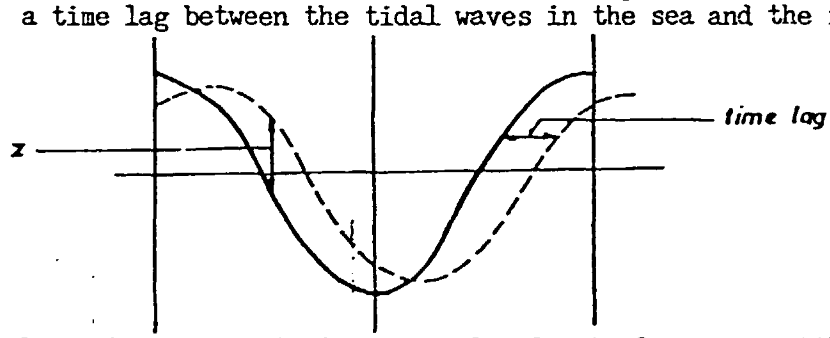
6. TIDES IN COASTAL INLETS AND RIVER MOUTHS

1. A tidal wave enters an inlet.



Assume the area of the lagoon is small. Then the water inside the lagoon rises/falls over this whole surface area at the same time. If there is a narrow opening, there is a head loss z, proportional to $\frac{v^2}{2g}$.

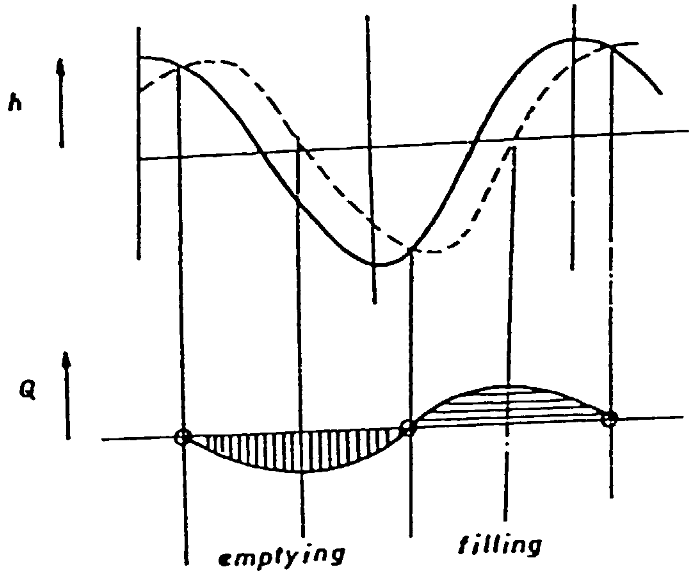
Due to this head loss there is during emptying/filling of the lagoon a difference z in the waterlevels between points A and B. This leads to a time lag between the tidal waves in the sea and the inlet.



When the sea is at its lowest level, the lagoon is still being emptied until both levels are equal. So the inlet is following the sea with a time lag and:
- the high water levels inside are somewhat lower than those at sea;
- the low water levels inside are somewhat higher than those at sea.

The curves for the water levels inside and outside show:
1. Rising water at sea: the level inside is lower than that at sea;
2. When the level of the sea is at its maximum and starts lowering the level inside is still increasing due to the ongoing filling of the inlet;
3. When the levels of the sea and in the lagoon are equal the filling stops and the current starts to reverse;
4. The water levels of the lagoon go down now, etc.

Now the time variation for the current in the opening is:

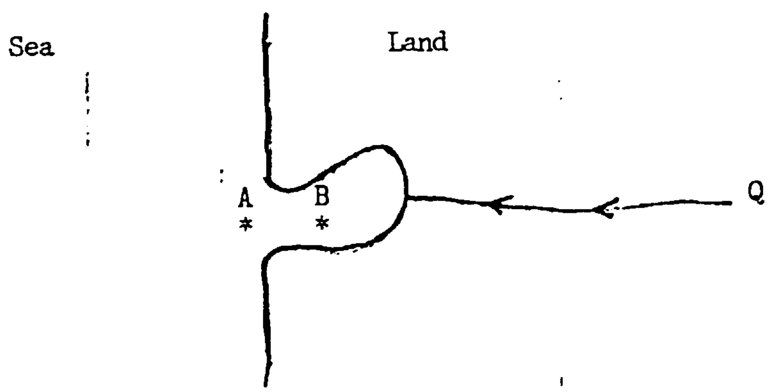


For the current in the opening the following terms are used:

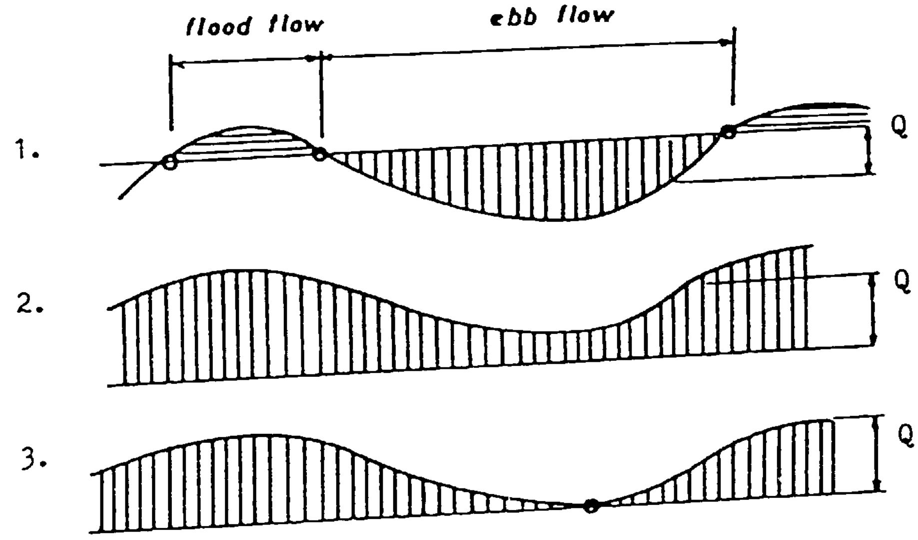
Ebb: Emptying current
Flood: Filling current
Slack water: Transition between ebb and flood (no current).

Over a longer period the total ebb flow volume equals the total flood flow volume.

2. Assume now that a river flows into the inlet.



Now there is an additional river flow with discharge Q. The tidal currents can now be superimposed on the river flow.



1. Q is smaller than the maximum flood flow:
   The flood volume becomes smaller; the ebb volume becomes bigger and the duration of the ebb gets longer. There are two points of zero velocity (slack water) per cycle.
2. Q bigger than the maximum flood flow:
   The influence of ebb and flood flow is still there, but the flow goes always out. Now there are no more slack water periods.
3. Q is equal to the maximum flood flow:
   The flow will stop for a very short time, resulting in one point of slack water only.

Every tidal river has such a point where slack water is occurring only once during the tidal cycle. Upstream of this point situation (2) prevails; downstream situation (1).

3. Estuaries

There is a large difference between a river and an estuary. Rivers transport the water, originating from precipitation, in one direction. In an estuary the water may flow in two opposite directions and the water level in the estuary is influenced by the tides of the sea.

In a normal river the discharge is determined by precipitation on the intake area or by seepage coming from the sides. The flow in an estuary will, additionally, be determined by the shape and dimensions of the estuary itself.

The morphology of an estuary with a loose bed will also be determined by the strength and character of the tides.

A tidal wave in an estuary may have a considerable length as shown in the following example. An approximation of the velocity of a tidal wave in an estuary with a depth of 2 m gives :

$$c = \sqrt{g * d} = \sqrt{10 * 2} = 4.43 \text{ m/sec.}$$

Length of this tidal wave :

$$L = c * T = 4.43 * 12 \text{ hrs:25 min } (44712 \text{ sec.})$$
$$= 198\ 074 \text{ m or round } 200 \text{ km.}$$

In longer rivers one would thus expect that more than one tidal wave is running at the same time. The energy in the wave may quickly dissipate inside a rough estuary, resulting in reduction of its height. Reduction of the wave height may be caused by :

1. friction
2. overflow of the riverbanks to neighboring areas (swamps, mangrove forests, lateral spillways, dike breaks, etc.).

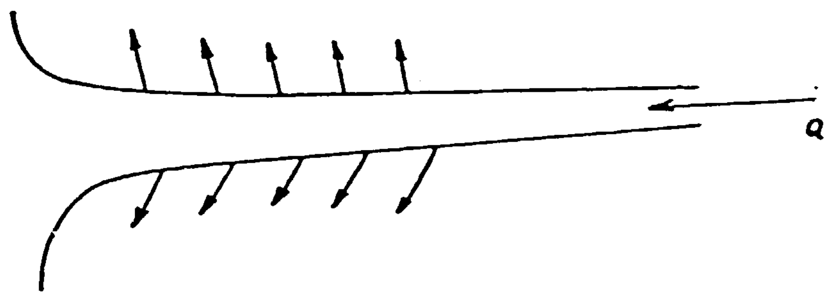


Fig. 37. Overland spilling gives reduction of the height of tidal wave.

However, in some cases the height of the tidal wave may also increase, due to reflection against obstacles/obstructions in the riverbed.

4. Deformation of tidal wave.

The crest of the tidal wave will travel somewhat faster than the lower parts of the wave, because its velocity of propagation depends on the water height.

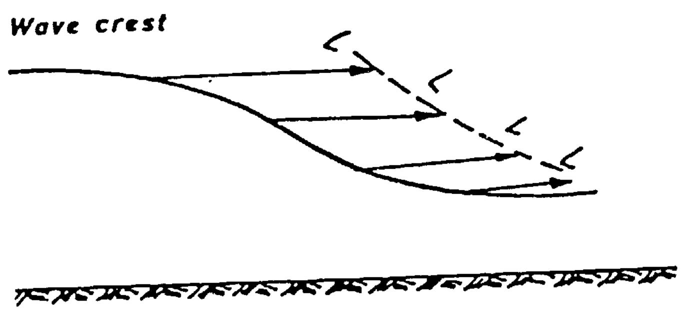


Fig. 38. Velocities in a tidal wave.

As a consequence the wave is deformed and becomes steeper. The longer the distance, over which the wave progresses the steeper its front will become. At the back-side of the wave the reverse happens, the slope of the tidal wave becomes flatter and flatter there.

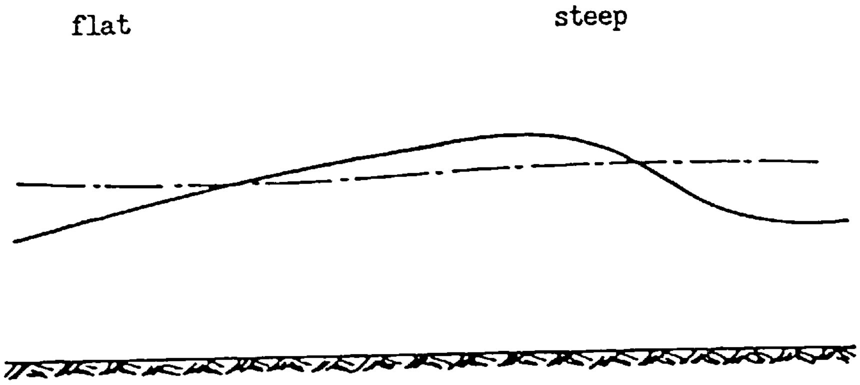


Fig. 39. Deformed tidal wave.

The result of this deformation is that the time during which the tide rises is shorter, whereas the falling of the water takes a longer time. Due to this deformation the tidal wave has become asymmetrical.
The bottom friction will further contribute to the deformation of the wave, so that in exceptional cases the front of the wave becomes very steep (a discontinuity has developed). The wave front gets now the shape of a roller, this phenomenon is called "tidal bore".

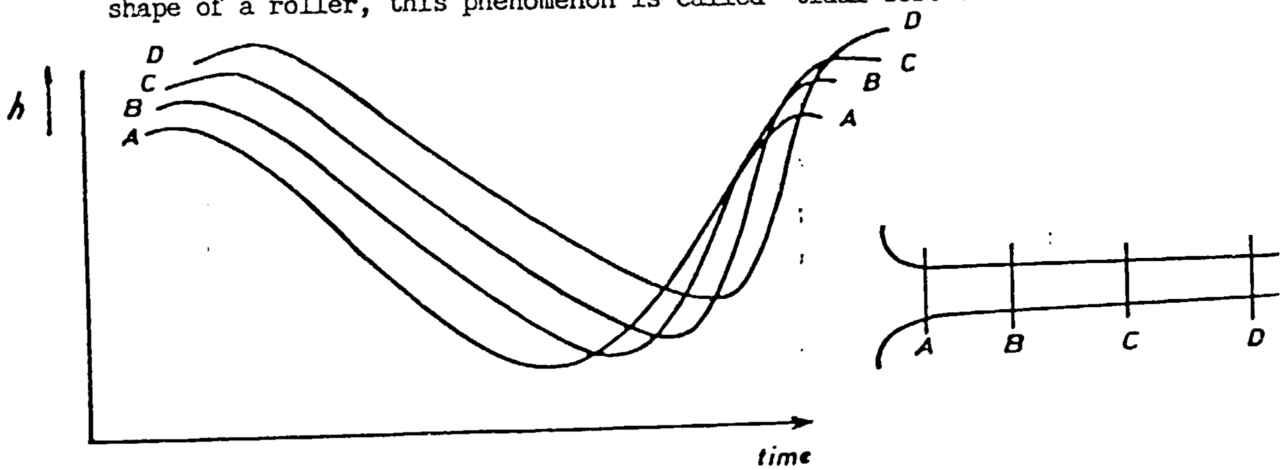


Fig. 40. The propagation of a tidal wave in an estuary.

For each location along the river the maximum flood level and the minimum ebb level can be drawn. The tidal waves are bounded by these lines of highest and lowest waterlevels. These two lines can easily be obtained by observation at a number of points along the estuary.

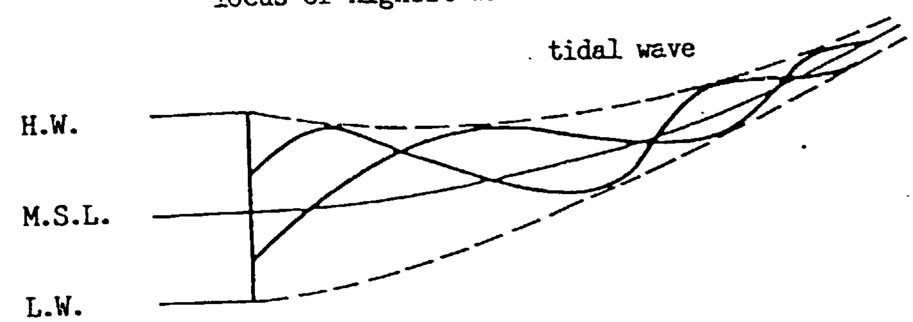


Fig. 41. Lines of maximum and minimum water levels along the estuary.

Plotting the discharge against time for various locations yields:

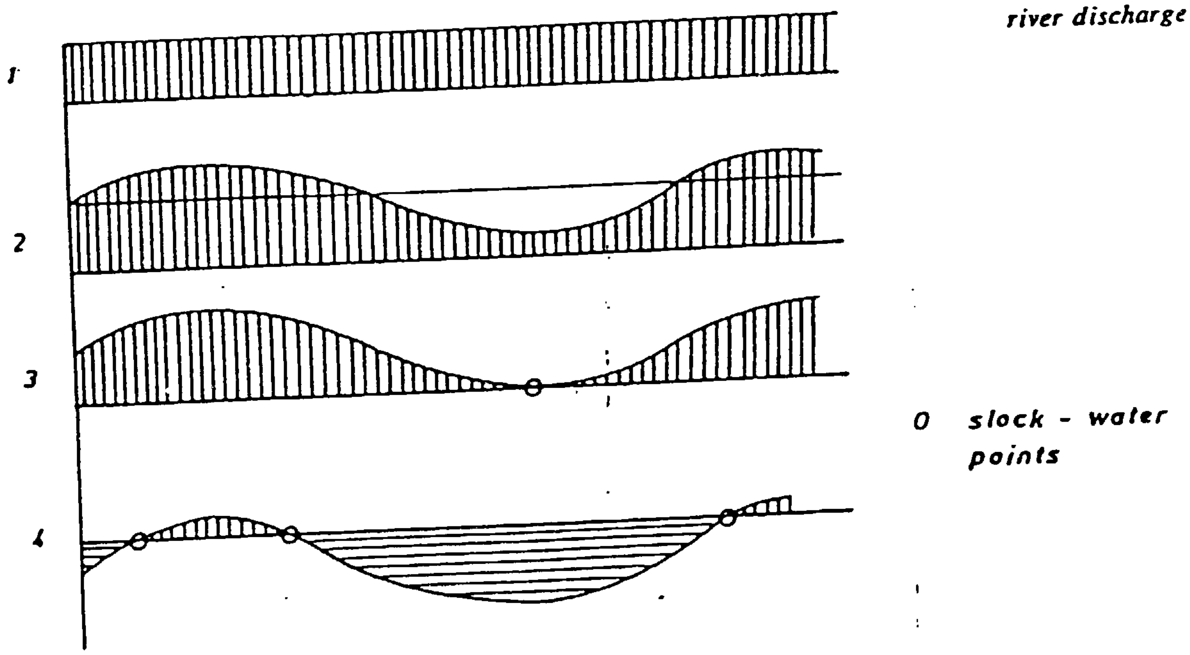


Fig. 42. Graph of discharge against time for various locations along the river.
1. Upstream - not influenced by tides;
2. Water levels influenced by tides;
3. Flow always towards the sea, sometimes reduced to zero;
4. Flow in both directions due to tides.

Observations for a number of locations along the river of the water levels at which the flow reverses its direction yield two lines, the locus of the slack-water levels on the flood and the locus of the slack-water levels on the ebb. One will find in this way the location of point B, the limit between full tidal river and tidal-influenced river.

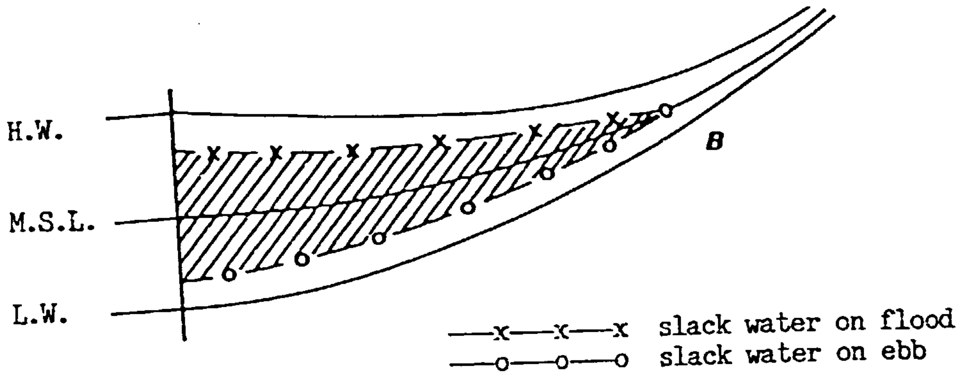


Fig. 43. Lines of slack water.

The volume between the two slack water lines upstream of a certain location yields a good approximation of the total flood volume upstream of that location (Error may be up to 15%).

As a complete measuring campaign of the flow along a tidal river requires much time and money, this approximative approach may be very useful in practice, where an estimate of tidal discharge is needed.

Remarks :

a. The flow does not change its direction at the same moment over the complete cross-section during the turning of the tide. Near the bottom the flow will still continue in its original direction, whereas near the surface the current has already reversed. The same holds true for the width of the river. First the flow direction reverses in the middle of the channel, later near the banks.

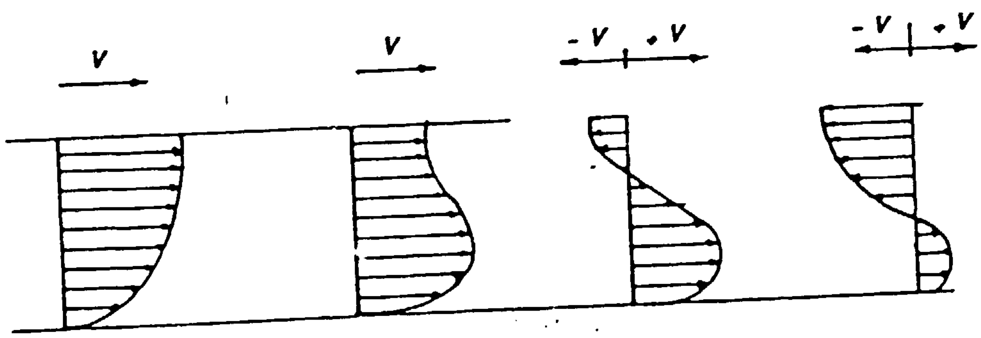


Fig. 44. Vertical velocity profiles, transition at various times.

b. The transition point B is not necessarily the same for all dis-discharges. The bigger the discharge Q, the more downstream will be the location of point B.

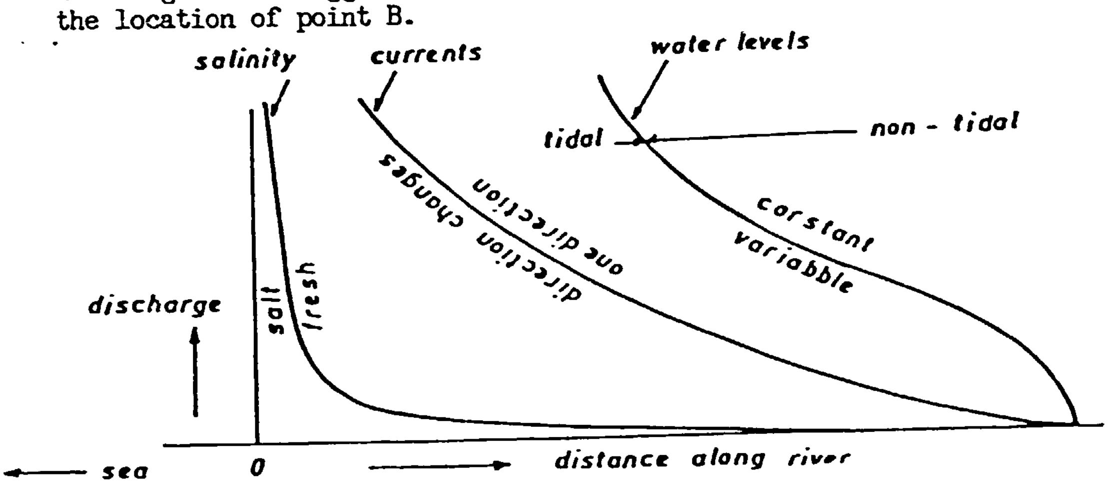


Fig. 45. Position of transition points at various river discharges.

If there is a control structure, such as a weir, this graph is of course not valid as the tide will not penetrate beyond such a structure.

xxxxxxxxxxxxxxxxxx

The following chapters of these notes will deal with:

7. Salt penetration into an estuary.
8. Tidal flow over sand banks and mud flats.
9. Hydrology of tidal rivers without embankments.
10. Hydrology of embanked low-land rivers.
11. Land subsidence in coastal areas.
12. Water supply in the coastal area.
13. Salinity in coastal reservoirs.
14. Design aspects of coastal reservoirs.

Francesco Bandarin

Università di Venezia

THE IMPACT OF RECREATIONAL USES ON THE COASTAL ZONE: PROCESSES AND MANAGEMENT ISSUES

SUMMARY

International Course on Coastal Zone Mangement

Session of October 22, 1992

LECTURR SUMMARY

"The impact of recreational uses on the coastal zone: processes and management issues."

by Francesco Bandarin, Professor of Planning Theory and Technique, Institute of Architecture, Venice.

Tourism has become in the last few decades one of the most significant uses of the coastal zone in many parts of the world. Its developement has triggered the growth of important local economies, and has at the same time generated land use and environmental conflicts.

The lecture will illustrate the development pattern of coastal tourism from the demand and supply sides, and will describe its most important models of evolution.

The international, national and regional structure of tourism and its major charachteristics (sunlust and wanderlust tourism) will be examined, in the attempt of defining the major trends concerning the coastal zone.

This will lead to an analysis of the spatial structure of tourism on islands and coastal resorts, with reference to concrete examples.

The lecture will deal with the environmental impacts of tourism development, mostly related to land consumption and the destruction of critical environments.

The orientations and policy recommendations of the major international programs on the coastal zone (Plan Bleu, MedPlan, OECD, EEC, etc.) will be presented, jointly with an evaluation of the most significant achievements in environmental protection.

Finally, the policy tools aimed at limiting and mitigating tourist impacts on the coastal zone will be discusses, with reference to concrete examples.

Mario Lenzi

Università di Padova

HYDROLOGICAL EFFECTS OF AGRICULTURAL PRACTICES

HYDROLOGICAL EFFECTS OF AGRICULTURAL PRACTICES

Ing. MARIO A. LENZI

AT THE WATERSHED LEVEL
TWO KINDS OF POLLUTION OCCUR:

(1) On the one hand "POINT POLLUTION",
EITHER OF URBAN ORIGEN (town waste)
OR OF INDRUSTRIAL ORIGEN (FACTORIES, MINES, Occ.)

* THESE ARE EASILY LOCALISED AND THEIR CONTROL DOES NOT USUALLY PRESENT ANY PROBLEMS, APART FROM FINANCIAL ONES.

(2) On the other hand there is "NON-POINT POLLUTION", IN PARTICULAR, AGRICULTURAL NON-POINT SOURCES OF POLLUTION.

* THIS IS MUCH MORE DIFFICULT TO PIN POINT BECAUSE OF THE FACT THAT IT IS WIDESPREAD THROUGHOUT THE ENVIRONMENT.

* THE TREATMENT OF THIS TYPE OF NON-POINT POLLUTION IS ALMOST IMPOSSIBLE A POSTERIORI, AND DEPENDS ON BEING CONTROLLED AT SOURCE

ALL THE INVESTIGATIONS SHOW THAT **AGRICULTURAL PRACTICES** PLAY A MAJOR PART IN THE DETERIORATION OF WATER QUALITY

THE ESSENTIAL ELEMENTS ARE:

- **SUSPENDED MATTER LINKED TO THE PHENOMENON OF EROSION** DUE TO **RUN-OFF**
- **NUTRIENTS** (NITROGEN AND PHOSPHORUS) GENERALLY INPUT BY **FERTILIZERS**
- **PESTICIDES**
- CLIMATE AND THE SIDE

. THE PRINCIPAL VEHICLE OF POLLUTION AT THE WATERSHED LEVEL IS WATER.

* RAINWATER RUN-OFF CARRIES AWAY EARTH. THE RESULTING EROSION, AS WELL AS DISSOLVED SUBSTANCES (NUTRIENTS, PESTICIDES, SALT) FLOWS TOWARDS THE RECEIVING ENVIRONMENT, WHICH IS GENERALLY **A RIVER**, BUT CAN ALSO BE **A RESERVOIR, LAKE, LAGOON OR THE SEA**

A LIST OF MATHEMATICAL MODELS WHICH HAVE HAD SOME OPERATIVE, PRACTICAL APPLICATIONS IS PROVIDED IN THE TABLE BELOW. WITHIN THE TABLE, THE PRINCIPAL AIMS, REASONS, AND UTILIZATIONS OF THESE MODELS ARE CLEARLY EMPHASIZED.

THESE MODELS ARE CALLED NAMELY

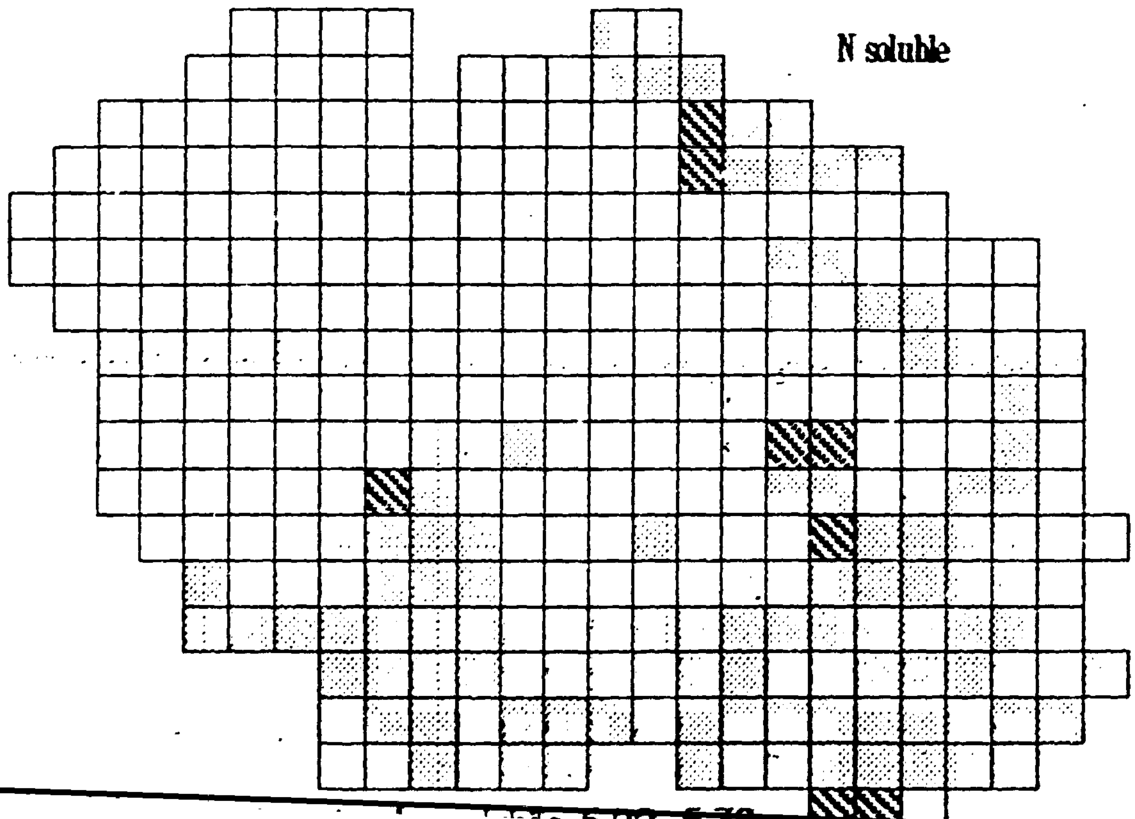
<u>DECISION-ORIENTED MODELS</u>

NON POINT SOURCES POLLUTION MODELS
(DECISION MODELS)

DECISION-ORIENTED MODELS, ESTABLISH RELATIONSHIPS BETWEEN **BEST MANAGEMENT PRACTICES (BMPs)** AND **WATER QUALITY**

TITLE	OBJECTIVE
AGNPS (BASIN SCALE)	TO SIMULATE SEDIMENT, NUTRIENT AND POLLUTANT TRANSPORT IN AN AGRICULTURAL WATERSHED
ANSWERS (BASIN SCALE)	TO PREDICT HYDROLOGIC AND EROSION RESPONSE OF AGRICULTURAL WATERSHEDS
CREAMS (FIELD SCALE)	TO SIMULATE HYDROLOGIC QUANTITIES, EROSION AND CHEMICAL TRANSPORT
GLEAMS	TO SIMULATE PESTICIDES AND NUTRIENTS LEACHING FROM AGRICULTURAL WATERSHEDS
SWAM (BASIN SCALE)	TO EVALUATED THE EFFECT OF DIFFERENT LAND USE AND MANAGEMENT PRACTICES ON A SMALL WATERSHED.

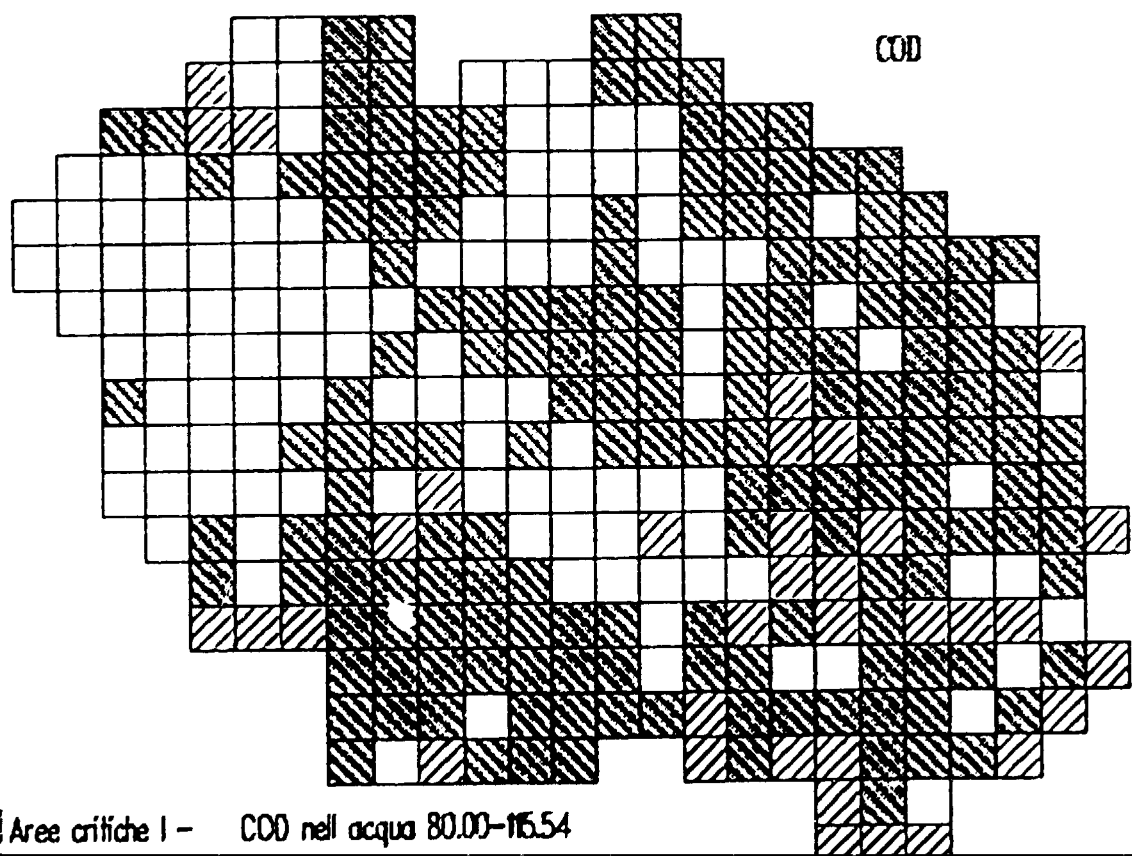
THE MODEL WAS DEVELOPED TO ANALYZE AND PROVIDE ESTIMATES OF RUNOFF WATER QUALITY FROM AGRICULTURAL WATERSHEDS RANGING IN SIZE FROM A FEW HECTARES TO UPWARDS OF 20,000 HA (50,000 ACRES). IT IS RELATIVELY SIMPLE TO USE AND RUNS ON AN IBM-COMPATIBLE PERSONAL COMPUTER.



COD, IS USED AS AN INDICATOR OF

OF POLLUTION.

- THE MODEL OPERATES ON A CELL BASIS. CELLS ARE UNIFORMLY SQUARE AREAS SUBDIVIDING THE WATER-SHEDS, ALLOWING ANALYSES AT ANY POINT WITHIN THE WATERSHED. POTENTIAL POLLUTANTS ARE ROUTED THROUGH CELLS FROM THE WATERSHED DIVIDE TO THE OUTLET IN A STEPWISE MANNER SO THAT FLOW AT ANY POINT BETWEEN CELLS MAY BE EXAMINED. ALL WATERSHED CHARACTERISTICS AND INPUTS ARE EXPRESSED AT THE CELL LEVEL.



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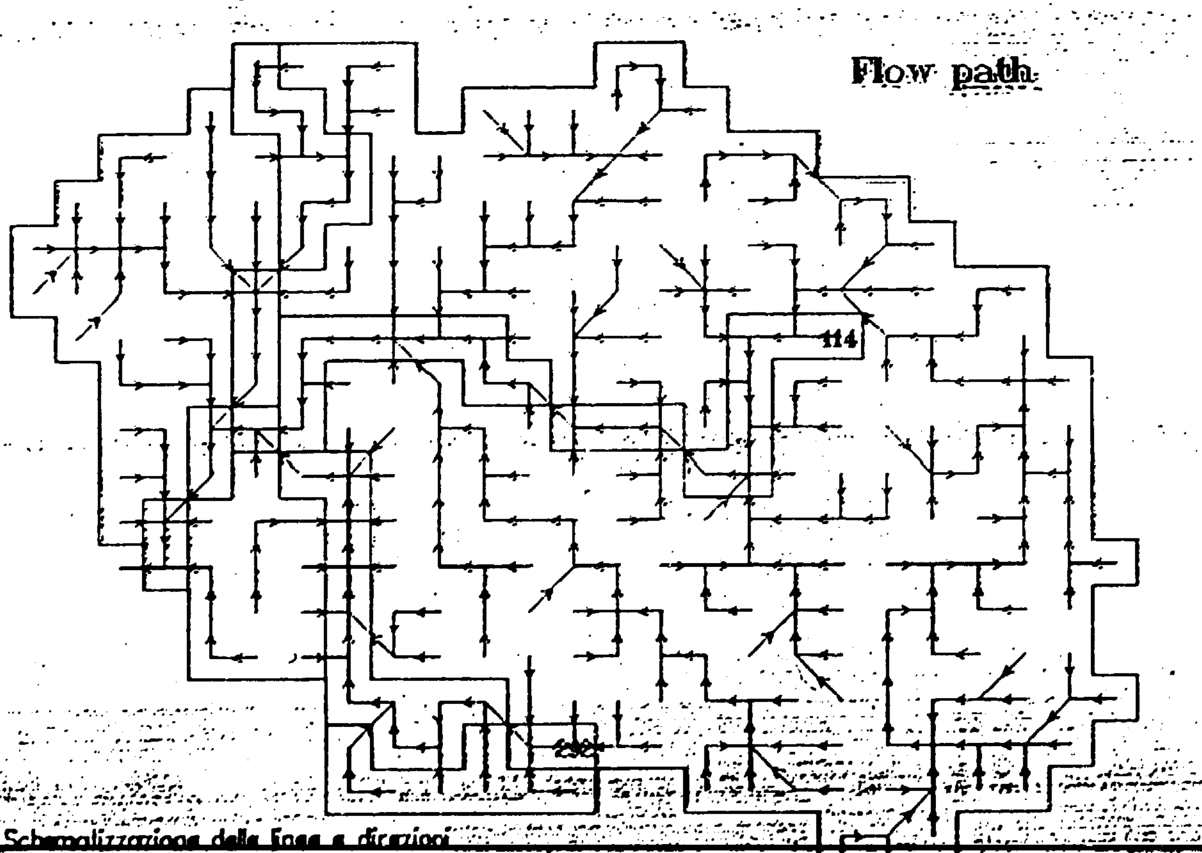
ENLARGING THE CELL SIZE REDUCES TIME AND LABOR, BUT THE SAVINGS, MUST BE BALANCED AGAINST THE LOSS OF ACCURACY RESULTING FROM TREATING LARGER AREAS AS HOMOGENEOUS UNITS.

THE MODEL IS DIVIDED INTO 4 COMPONENTS:

- HYDROLOGY
- EROSION AND SEDIMENT TRANSPORT
- CHEMICAL TRANSPORT
- POINT SOURCE INPUTS



→ Schematizzazione della Fase e direzioni

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

where Q = is THE RUNOFF VOLUME

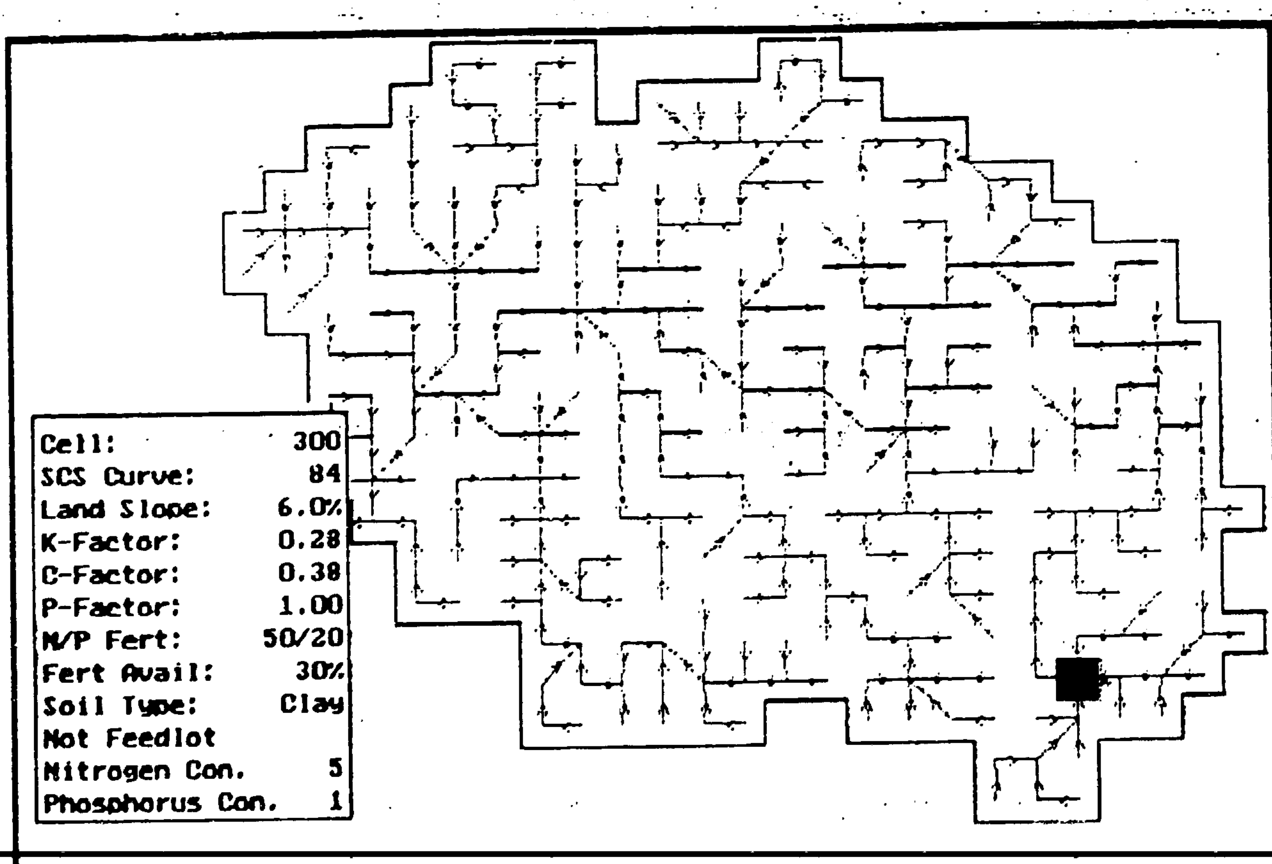
P = is THE RAINFALL

S = is A RETENTION PARAMETER

THE RETENTION PARAMETER is DEFINED IN TERMS OF A CURVE NUMBER (CN) AS FOLLOWS:

$$S = \frac{1{,}000}{CN} - 10$$

THE CURVE NUMBER DEPENDS UPON LAND USE, SOIL TYPE, AND HYDROLOGIC SOIL CONDITION. THIS METHOD WAS CHOSEN BECAUSE OF ITS SIMPLICITY AND WIDESPREAD USE AMONG THE PRINCIPAL USER AGENCIES FOR WHICH THE MODEL WAS DEVELOPED.



WHERE Q_p = is the PEAK FLOW RATE IN $M^3 s^{-1}$

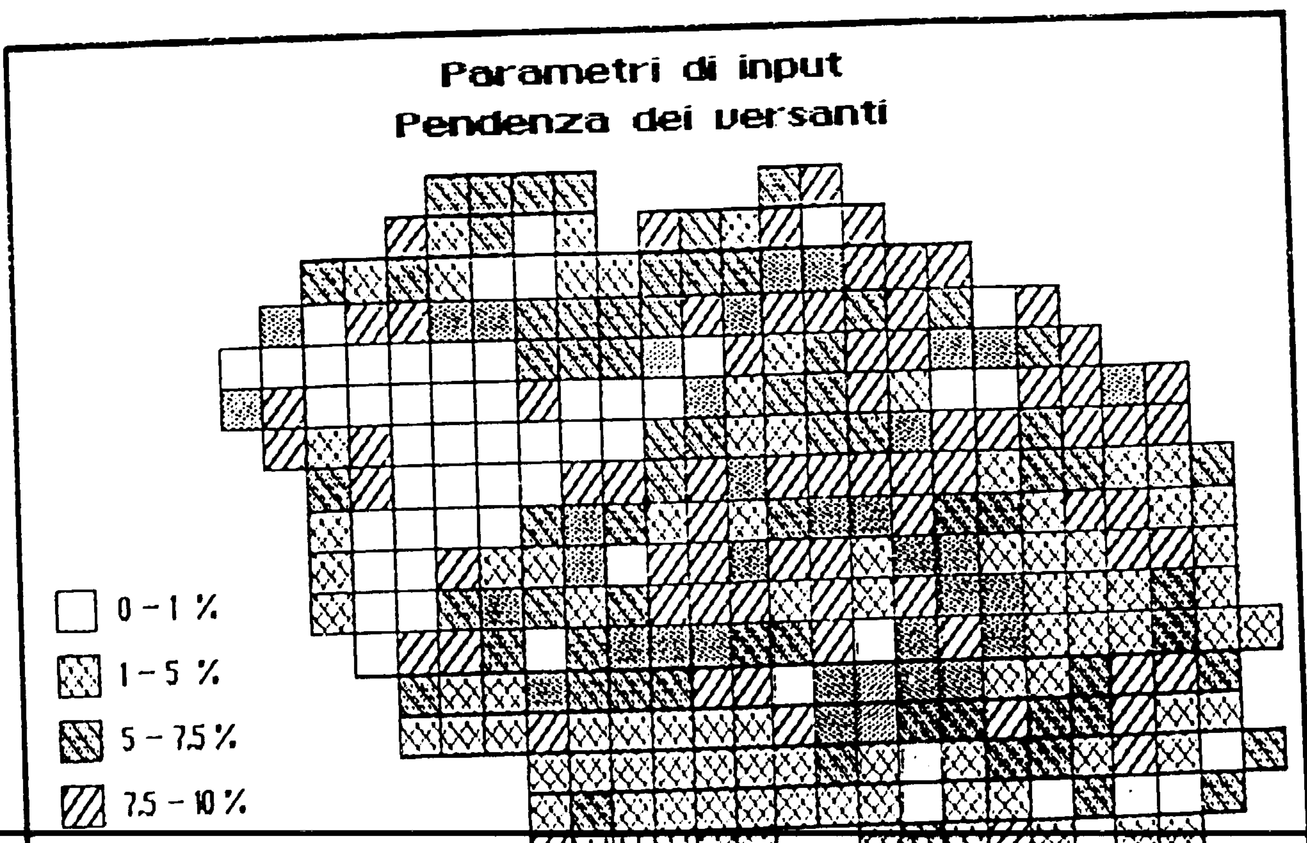
A = is the DRAINAGE AREA IN KM^2

CS = is THE CHANNEL SLOPE IN M/KM

RO = is THE RUNOFF VOLUME IN MM

LW = is THE WATERSHED LENGTH WIDTH RATIO
CALCULATED BY L^2/A
L = is the WATERSHED LENGTH

VALUES OF THE COEFFICIENTS WERE DETERMINED FROM FIELD MEASUREMENTS.



WHERE SL = IS THE SOIL LOSS

EI = IS THE PRODUCT OF THE STORM TOTAL KINETIC ENERGY AND MAXIMUM 30-MINUTE INTENSITY

K = IS THE SOIL ERODIBILITY FACTOR

LS = IS THE TOPOGRAPHIC FACTOR

C = IS THE COVER AND MANAGEMENT FACTOR

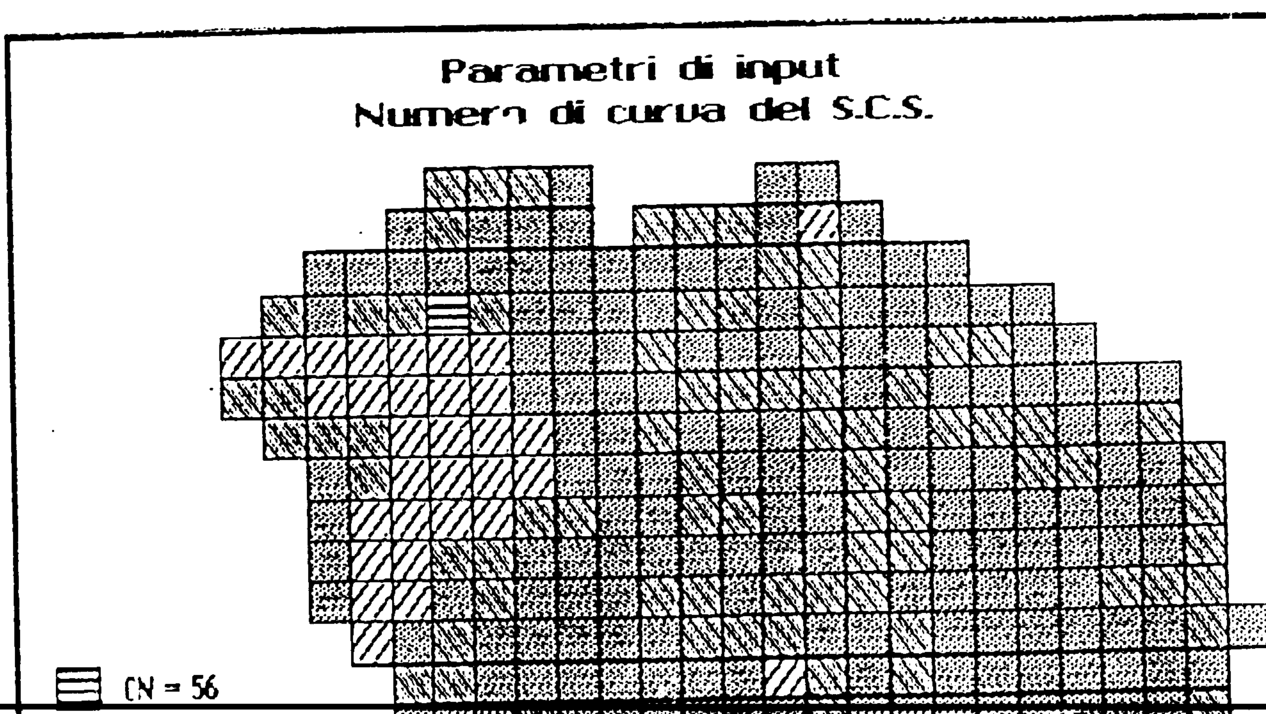
P = IS THE SUPPORTING PRACTICE FACTOR

SSF = IS A FACTOR TO ADJUST FOR SLOPE SHAPE WITHIN THE CELL

SOIL LOSS IS CALCULATED FOR EACH CELL OF THE WATERSHED.

ERODED SOIL AND SEDIMENT YIELD ARE SUBDIVIDED INTO 5 PARTICLE SIZE CLASSES

- CLAY
- SILT
- SMALL AGGREGATES
- LARGE AGGREGATES
- SAND



LANE.

EFFECTIVE TRANSPORT CAPACITY IS COMPUTED USING A MODIFICATION OF THE BAGNOLD STREAM POWER EQUATION AS FOLLOWS :

$$q'_s = \eta q_s = \eta k \frac{\tau V^2}{V_{ss}}$$

WHERE q_s = is the TRANSPORT CAPACITY

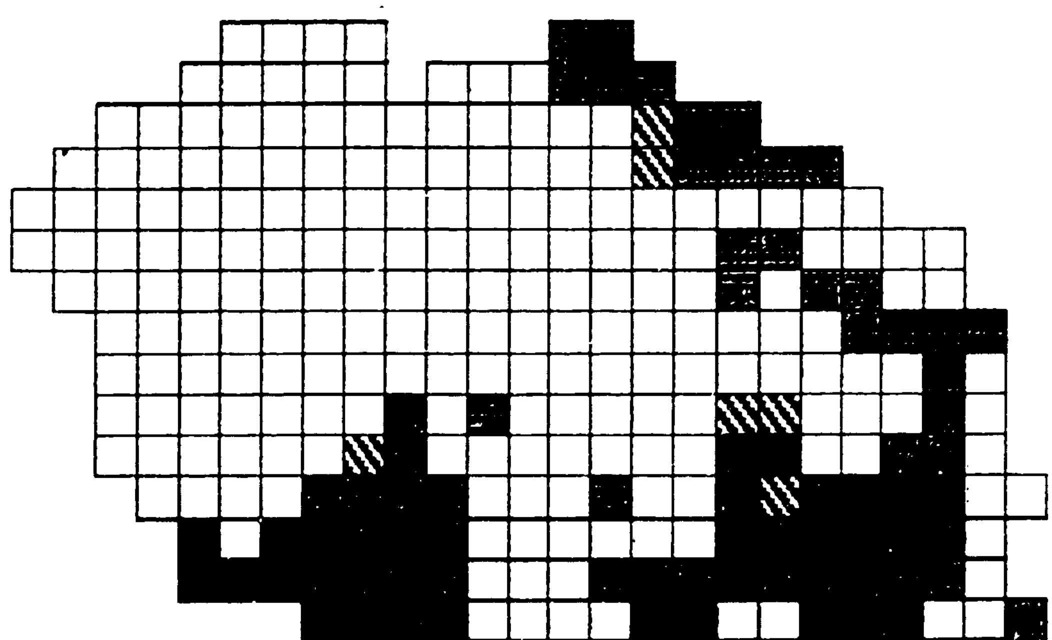
η = is AN EFFECTIVE TRANSPORT CAPACITY FACTOR

τ = is THE SHEAR STRESS

V = is THE AVERAGE CHANNEL FLOW VELOCITY DETERMINED BY MANNING'S EQUATION.

Output chimico

Rilascio di azoto solubile nell'acqua di deflusso



CALCULATIONS ARE DIVIDED INTO SOLUBLE AND SEDIMENT ADSORBED PHASES. NUTRIENT YIELD IN THE SEDIMENT ABSORBED PHASE IS CALCULATED USING TOTAL SEDIMENT YIELD FROM A CELL, AS FOLLOWS:

$$NUT_{SED} = (NUT_F)\, Q_s(x)\, E_R$$

WHERE NUT_{SED} = IS N OR P TRANSPORTED BY SEDIMENT

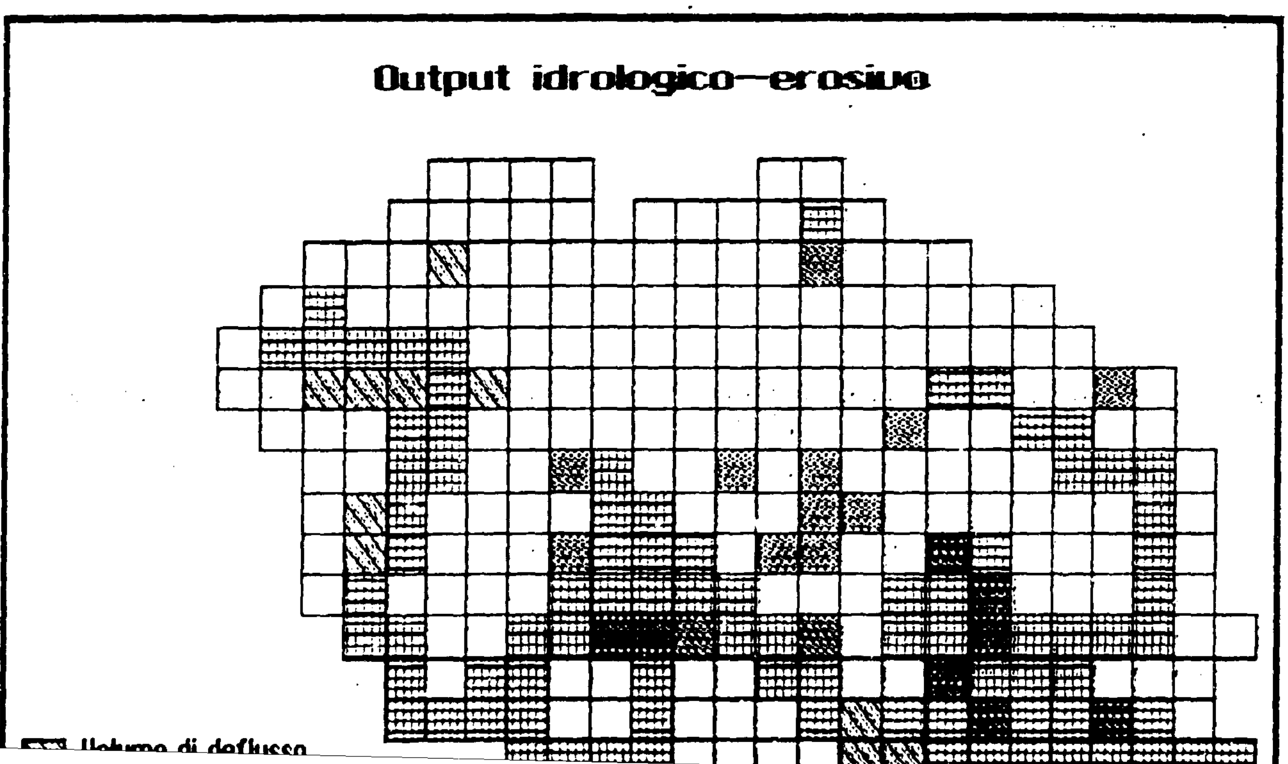
NUT_F – IS N OR P CONTENT IN THE FIELD SOIL

E_R = IS THE ENRICHMENT RATIO CALCULATED AS:

$$E_R = 7.4\, Q_s(x)^{-0.2}\, T_F$$

WHERE $Q_s(x)$ – IS THE SEDIMENT YIELD

T_F = IS A CORRECTION FACTOR FOR SOIL TEXTURE



WHERE NUT_{SOL} = IS THE [illegible]
IN THE RUNOFF

C_{NUT} = IS THE MEAN CONCENTRATION OF SOLUBLE N OR P AT THE SOIL SURFACE DURING RUNOFF

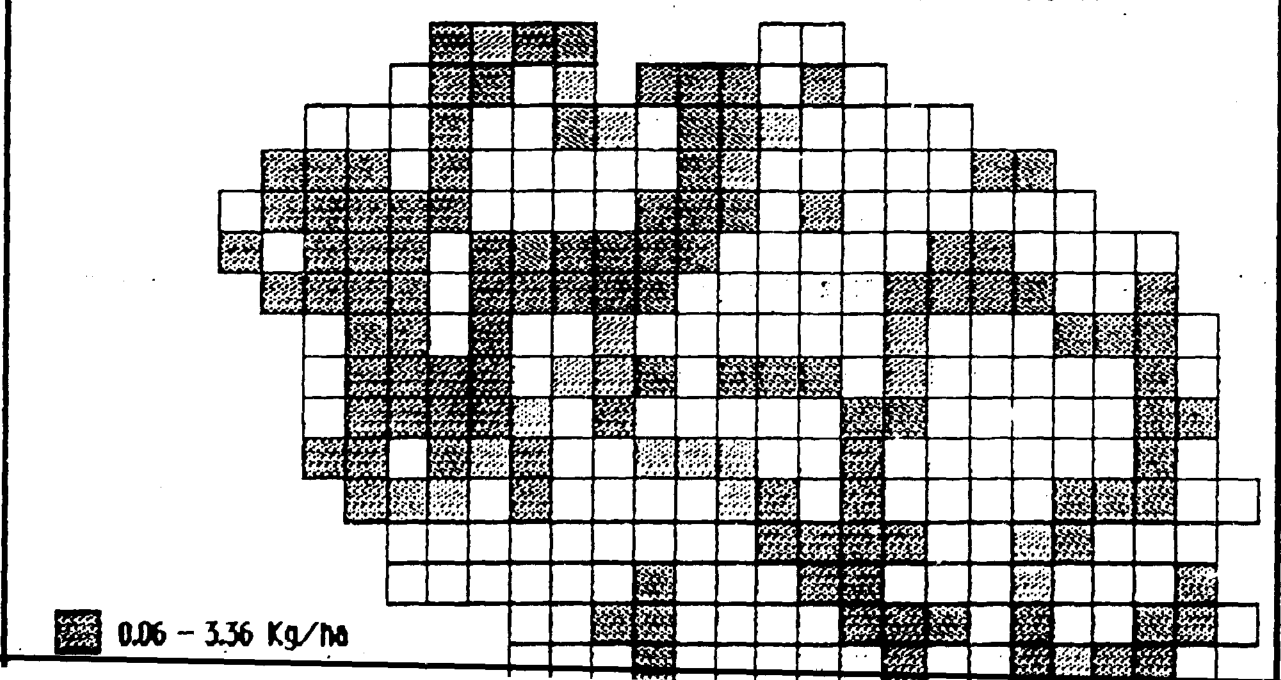
NUT_{EXT} = IS AN EXTRACTION COEFFICIENT OF N AND P FOR MOVEMENT INTO RUNOFF

Q = IS THE TOTAL RUNOFF

COD IN THE MODEL IS ASSUMED SOLUBLE.

ESTIMATES OF COD IN RUNOFF ARE BASED ON CALCULATED RUNOFF VOLUMES AND AVERAGE CONCENTRATION OF COD IN THAT VOLUME. BACKGROUND CONCENTRATION OF COD AVAILABLE IN THE LITERATURE ARE USED AS A BASIS FOR PREDICTING COD CONCENTRATIONS FROM EACH CELL. SOLUBLE COD IS ASSUMED TO ACCUMULATE WITHOUT ANY LOSSES.

Output chimico
Quantita' di azoto rilasciato nei sedimenti



4 PRECIPITACION (INCHES)

5 ENERGY-INTENSITY VALUE (EI)

CELL PARAMETER

1 CELL NUMBER

2 NUMBER OF THE CELL INTO WHICH IT DRAINS

3 SCS CURVE NUMBER

4 AVERAGE LAND SLOPE %

5 SLOPE SHAPE FACTOR (UNIFORM, CONVEX, CONCAVE)

6 AVERAGE FIELD SLOPE LENGTH (feet)

7 AVERAGE CHANNEL SLOPE (%)

8 (n) MANNINGS ROUGHNESS COEFFICIENT FOR THE CHANNE.

9 SOIL ERODIBILITY FACTOR (K) FROM USLE

10 CROPPING FACTOR (C) FROM USLE

11 PRACTICE FACTOR (P) FROM USLE

12 ASPECT (Drainage direction from the cell)

13 SOIL TEXTURE (SAND, SILT, CLAY)

14 FERTILIZATION LEVEL (Zero, low, medium, high)

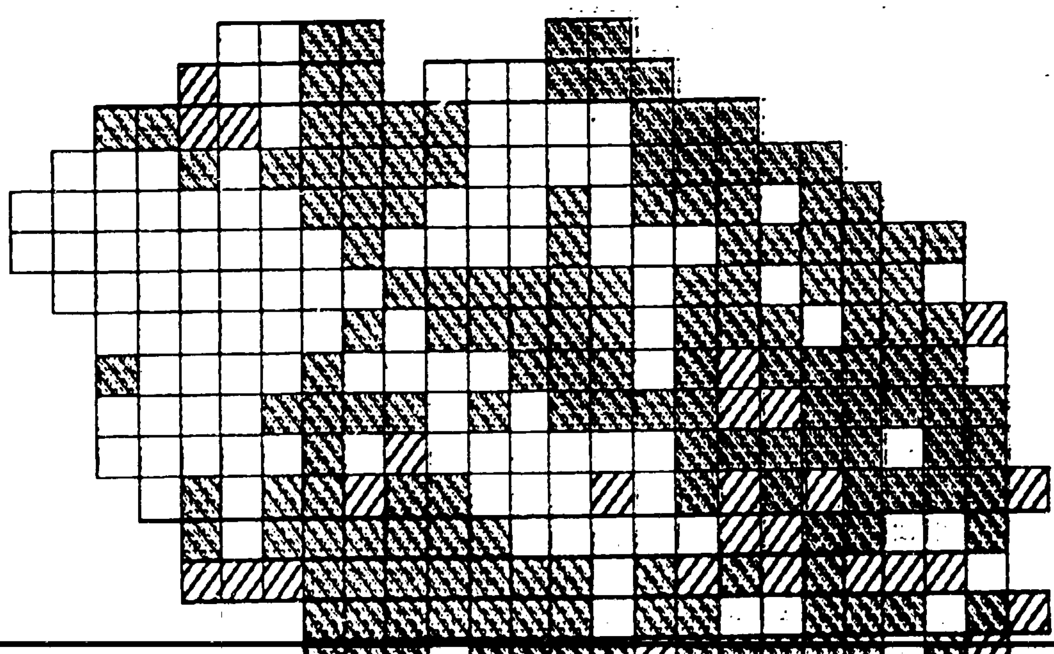
15 POINT SOURCE INDICATOR

16 GULLY SOURCE LEVEL (tons in a cell)

17 CHEMICAL OXYGEN DEMAND FACTOR

Output chimico

Stima a livello di cella della COD nell'acqua di deflusso



- SEDIMENT YIELD (tons.)
- SEDIMENT CONCENTRATION (ppm)
- SEDIMENT PARTICLE SIZE DISTRIBUTION
- UPLAND EROSION (tons/acres)
- AMOUNT OF DEPOSITION (%)
- SEDIMEN GENERATED WITHIN THE CELL

3) Chemical output

NITROGEN

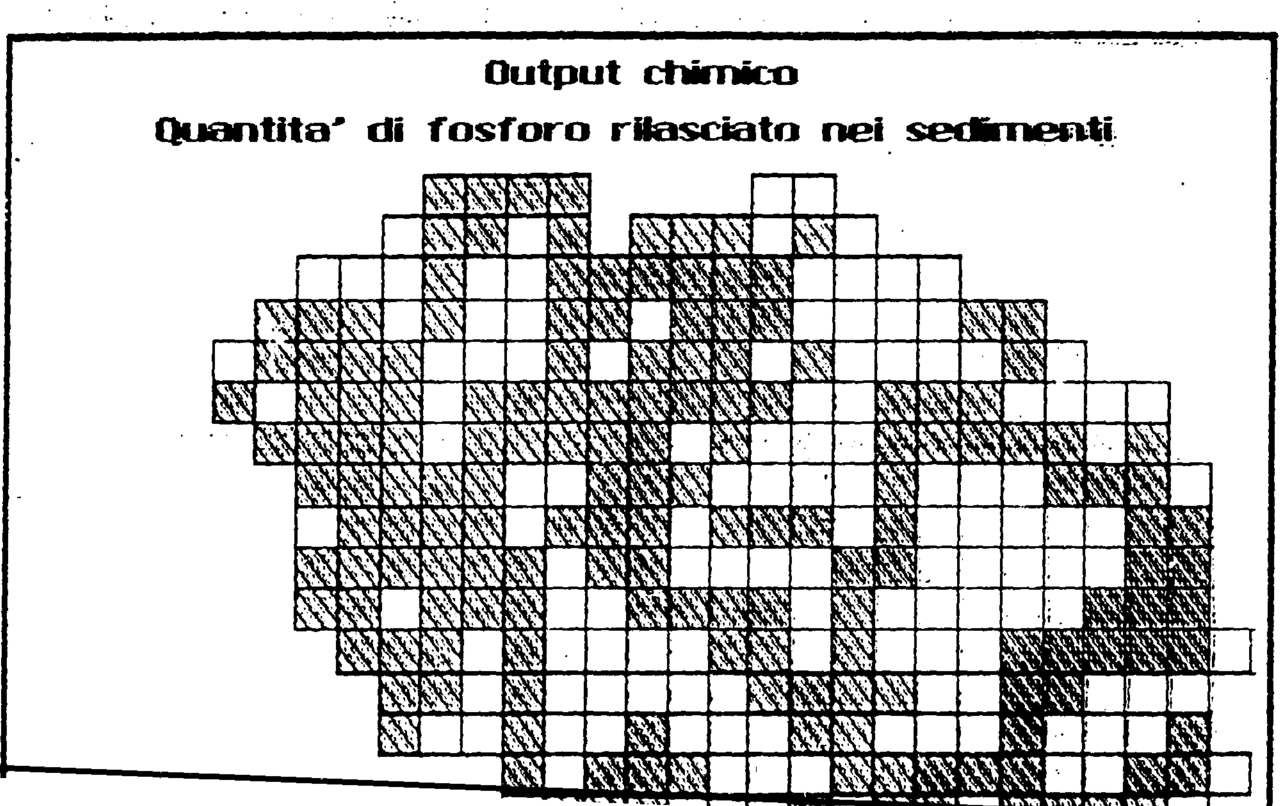
- SEDIMENT ASSOCIATED MASS (POUNDS/ACRE)
- CONCENTRATION OF SOLUBLE MATERIAL (ppm)
- MASS OF SOLUBLE MATERIAL (POUNDS/ACRE)

PHOSPHORUS

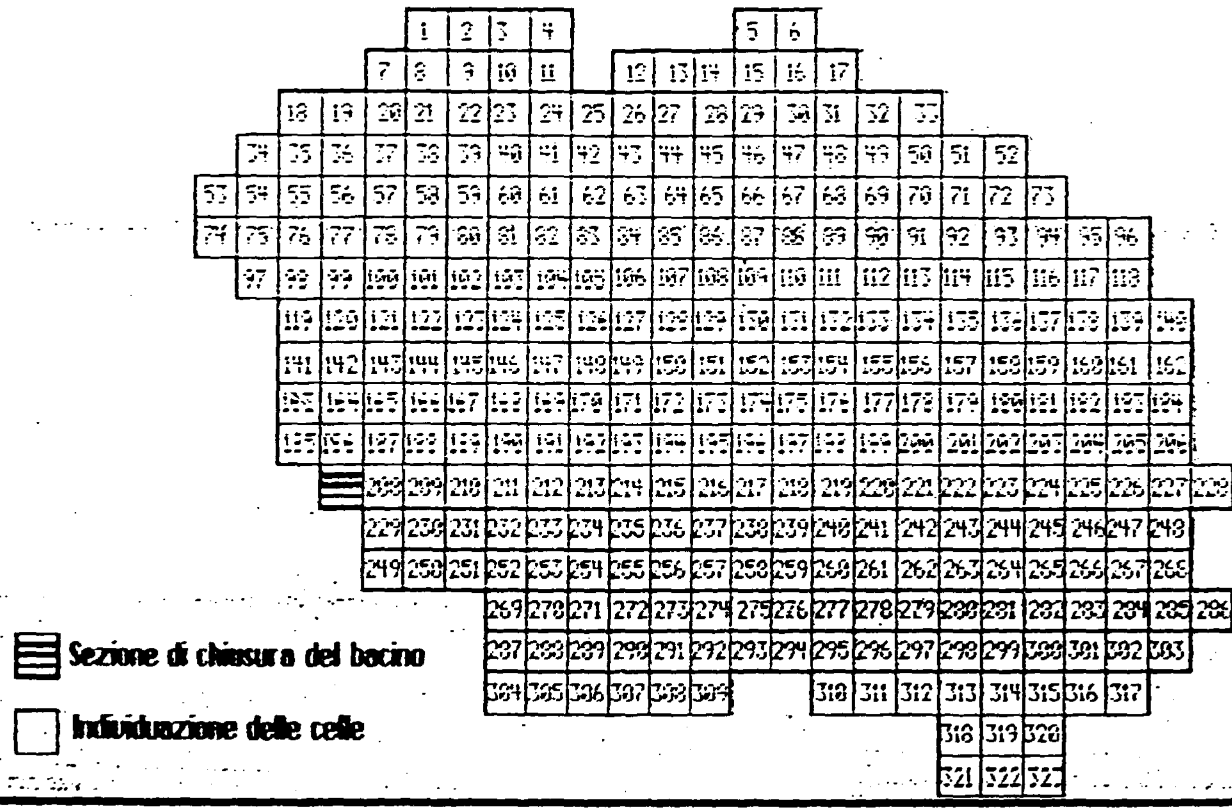
- SEDIMENT ASSOCIATED MASS (pounds/Acre)
- CONCENTRATION OF SOLUBLE MATERIAL (ppm)
- MASS OF SOLUBLE MATERIAL (pounds/ACRE)

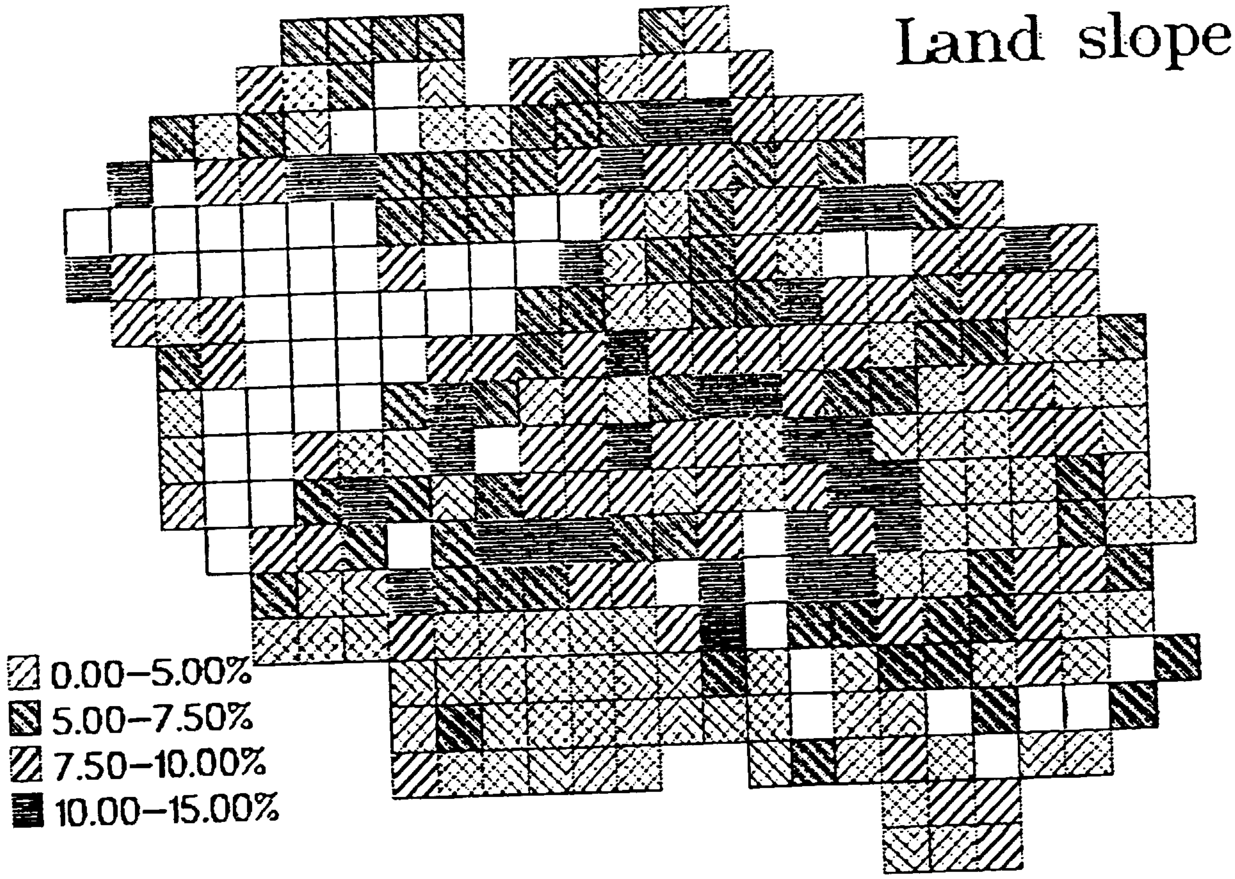
CHEMICAL OXYGEN DEMAND

- CONCENTRATION (ppm)
- MASS (pounds/acre)

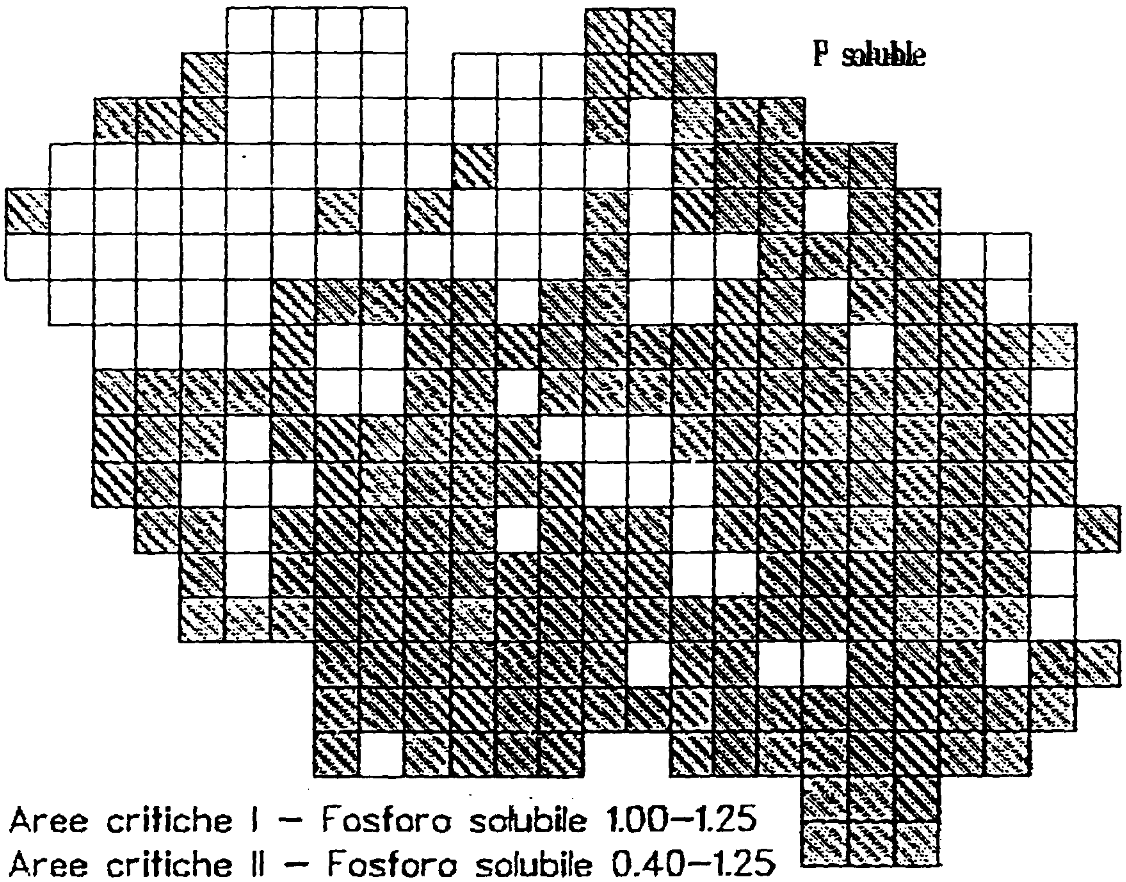

Output chimico
Quantita' di fosforo rilasciato nei sedimenti

Suddivisione del bacino in singole unita' geografiche (celle)





Land slope
0.00–5.00%
5.00–7.50%
7.50–10.00%
10.00–15.00%



Aree critiche I – Fosforo solubile 1.00–1.25
Aree critiche II – Fosforo solubile 0.40–1.25
lb/acro

Capture Fisheries and Integrated Coastal Area Management (ICAM)

Dr. A.D. Insull
FAO

INTERNATIONAL INSTITUTE FOR EARTH, ENVIRONMENTAL AND MARINE SCIENCES AND TECHNOLOGIES (IIEM)

Course on Coastal Zone Management, 19-30 October 1992

Capture Fisheries and Integrated Coastal Area Management (ICAM)

Introduction

These notes are provided in the anticipation that they will assist Course participants to understand, in some degree, the background to the subject, and help to stimulate discussion within the limited time available.

They begin by looking at a definition of sustainability, and its implications for development practice. Some of the main considerations which have to be taken into account in planning development in coastal areas are then looked at, followed by a consideration of the unique features of capture fisheries which bear on fishery sectoral planning. The main part of the notes are taken up with a consideration of the issues within and threats to, the sustainability of capture fisheries. Fishery sectoral planning has to deal with these threats and issues. Some of the factors which may worsen the threats to sustainability are then listed, before describing some of the general principles which should guide sectoral planners. There then follows a short section on an approach to ICAM within sectoral planning.

The final part of the lecture notes provides some general guidance on fishery sector planning initiatives which might be taken. It will be appreciated that these are general in character and the planning process will vary greatly from one situation to another.

Note

These lecture notes represent the views of the presenter and are not necessarily those of FAO.

Acknowledgements

Ecologically Sustainable Development Working Groups, Final Report - Fisheries, November 1991, Australian Government Publishing Service, Canberra.

Marine Environment Support - Guidelines for SIDA: Environment and Natural Resources Management in Marine and Coastal Areas and in Larger River Systems, Natural Resources Management Division, SIDA, (in draft).

Sustainability

The Definition Adopted by FAO

"Sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continuous satisfaction of human needs for present and future generations. Such sustainable development (in the agricultural, forestry and fishery sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically and socially acceptable." (Definition adopted by the FAO Council, November, 1988).

It can be said, therefore, that sustainable development and environmental issues cut across most of the activities of the agricultural, forestry and fishery sectors.

Some Implications of Adopting Sustainable Development

- improvement in material and non-material wellbeing;
- intergenerational equity;
- intragenerational equity;
- maintenance of ecological systems and biodiversity;
- global ramifications, including international trade and international cooperation; and
- dealing cautiously with risk, uncertainty and irreversibility.

Environmental Considerations in Marine and Coastal Areas

- they are the ultimate recipients for environmental degradation and pollutants released to the air, land, and water, which are usually carried by water into the coastal areas, including coastal seas;
- almost all activities in coastal areas affect other uses of the resources;
- in many countries, and in most developing countries, the coastal areas are of critical economic importance.

Unique Features of Capture Fisheries

- fishing is primarily a "hunting" activity, which, among other things, tends to generate certain attitudes among fishermen and, importantly, raises the question of property rights;

- fish are difficult to observe in their habitats, so knowledge of fish resources is poorer than that of land-based resources;
- the linkages within aquatic systems can lead to unforseen "downstream" effects from "outside" a fishery.

Issues and Threats to Sustainability

- internal factors;
- external factors;
- impact of fishing on the environment.

Internal Factors

- poor information;
- risk and uncertainty;
- excess fishing capacity;
- access and/or property rights.

External Factors

- habitat degradation, e.g.,
  - from increased urbanisation, including tourism development, and infrastructure development, resulting in pollution from runoff and sewage disposal, and siltation and water turbidity which may destroy fish breeding and nursery areas;
  - from development of wetlands, for urban development and/or agriculture and/or aquaculture, destroying fish breeding and nursery areas;
  - poor land clearing and irrigation practice which increase levels of salinity, suspended sediment, nutrients and water turbidity, which may lead to loss of habitats, such as coral reefs and seagrass beds;
  - from offshore minerals and petroleum exploitation which may increase siltation, so reducing the productivity of a habitat;
  - from sand mining which will produce turbidity and siltation , and coral mining which destroys fish habitats.

- direct toxic effects, e.g.,
  - pollutants from industry and urban areas producing fish kills;
  - discharge of organic wastes leading to lowered dissolved oxygen levels (e.g. from industry, agriculture, aquaculture);
  - fish kills by heavy metals;
- production of contaminant levels in economic species making them unsaleable, e.g.,
  - agricultural and industrial runoff producing "red tide" which may seriously threaten fish, particulary molluscs;
  - contamination from heavy metals, organochlorines, etc.

Impact of Fishing on the Environment

On the physical structure, e.g.,

- trawling and dredging;
- use of explosives, especially on coral reefs.

On water quality, e.g.,

- use of poisons;

On by-catch and wildlife, e.g.,

- by-catch of trawling operations;
- capture of non-target species by gill nets and pelagic driftnets;
- albatross kills from long-lining (there is also an economic cost to the long-liner fishermen).

On genetic diversity, e.g.,

- overfishing may threaten particular stocks which may result in a reduction of their genetic diversity, so reducing the fitness of those resources.

Accelerating Factors

- high rate of population increase;
- poverty, worsened through decreasing access to resources;

- unregulated activities;
- insufficient awareness or knowledge of the sustainability of resources;
- inappropriate legal systems;
- inability to enforce laws and regulations.

Some General Principles

- the orientation of development to improving the living conditions of the poorer sectors of society;
- develop awareness of the need for integrated development within an ecologically sustainable framework;
- develop institutional mechanisms for effective management of the resources.

A Cross-sectoral Approach to Fisheries Development Planning

Sectoral planning, and programme and project design and implementation are responsibilities of line ministries. In very few cases is effective ICAM planning possible - for example, by a cross-sectoral planning agency for ICAM - outside the line agencies. In other words, ICAM should be part of the planning process within the traditional line agencies, with a coordinating agency having certain specific functions, Among the most important of these will, in most cases, be some form of arbitration function for inter-sectoral differences over resource allocation.

Some Possible Actions in the Fishery Sector

<u>Information Requirements</u>

- <u>Description of the sector</u>

  Description of the capture fishery and marine aquaculture sector, including its location, size, structure, species of commercial importance, existing management measures, legislation framework.

- <u>Environmental information</u>

  (i) Use of available information to:

  (a) assess whether there are any endangered or threatened species;

  (b) assess impact of fishing and marine aquaculture on the ecosystem and physical damage to the benthos; and

(c) assess impact on the ecosystem from external causes of pollution and/or habitat degradation.

(ii) information on marine parks and other conservation areas.

(iii) information on productivity (growth and mortality) and biomass (need to establish sustainable yields).

(iv) establishment of key criteria to monitor any overfishing.

(v) identification of research requirements.

- Economic and social information

(i) Economic and social significance (e.g. earnings, employment, food supplies, net foreign exchange benefits).

(ii) need to establish any foregone (or potentially foregone), resulting from any impact on the sector, profits, incomes, supplies of fish to markets, and any damage (or potential damage) to social relationships within communities, by using historical and actual information on vessels' costs and earnings, distribution of earnings between participants in the fishery, economic and social linkages, fish distribution chain margins, margins of input suppliers, and alternative employment opportunities.

(iii) identification of research requirements.

- Institutional and organizational information

(i) Need to establish any overlapping and/or gaps in institutional responsibilities; interactions between fisheries institutions and other government agencies responsible for land use planning and management, and coastal development policy; institutional technical capacitates; research and training institutions and capabilities;

(ii) need to identify institutions performing, or which might perform, a management function.

Administrative and Institutional Arrangements

- Role of public sector management arrangements

(i) to address those areas where fisheries resources management might be improved;

(ii) to assess cross sectoral impacts on fisheries in biological and economic terms.

- <u>Institutional options</u>

  Selection of appropriate institutional mechanisms for (a) fisheries management planning and (b) cross-sectoral and intra-sectoral conflict resolution. Importance of decentralisation. Role of public participation and/or consultation.

<u>Planning for Sustainable Development</u>

- <u>Management strategy formulation</u>

  Description of long-term objectives (recognition of risk-averse decisions and precautionary approach to management) and means of achieving them (institutional changes, need for appropriate legislative framework, information systems and research); timeframe; recognition of commercial and sport fisheries, and subsistence fisheries within a broader cost-benefit framework of the coastal ecosystem; need for public input; need for assessment of new capture fishery and aquaculture developments

- <u>Interim fisheries management plans</u>

  Possible need. Content.

- <u>Formal fisheries management plans</u>

  Description of the elements of fisheries management plans, e.g.:

  - aims and policies;
  - fishing capacity;
  - access rights;
  - integration of sport fishing into the overall management of the fishery resource;
  - integration of subsistence fishing into the overall management of the fishery resource;
  - regulations, legislation;
  - other policy instruments (research, information systems, training, public education, etc.);
  - performance criteria;
  - monitoring and enforcement of regulations;

- impact assessment (biological and economic);
- conflict resolution (intra- and inter- sectoral);
- impact of plans on the ecosystem;
- impact of plans on all concerned;
- manpower and financial resources required, sources of funding, timeframe.

A.D. Insull, Fishery Policy and Planning Division, FAO, Rome, Italy, 19 October 1992

Aquaculture in the Coastal Environment

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Course on Coastal Zone Management, 19-30 October 1992

AQUACULTURE IN THE COASTAL ENVIRONMENT[1,2]

1. INTRODUCTION

Aquaculture interacts with the environment. It utilizes resources and causes environmental changes. Most interactions have beneficial effects. There have been substantial socio-economic benefits arising from the expansion of aquaculture. These benefits include increased income, employment, foreign exchange earnings and improved nutrition. Unfortunately, some coastal aquaculture practices have resulted in adverse effects on ecosystems.

There is concern about the potential environmental implications of coastal aquaculture development, comprising the adverse effects of aquaculture operations on the environment as well as the consequences of increasing aquatic pollution affecting feasibility and sustainable development of aquaculture. Environmental problems have resulted from conversion of wetland habitats, nutrient and organic waste discharges, introduction of exotic species, chemical usage, as well as from deterioration of water quality and decreasing availability of suitable sites for aquaculture.

These notes are intended to 1) summarize existing and potential environmental interactions of aquaculture in coastal areas and 2) to highlight possible measures to achieve environmentally-acceptable and sustainable development of coastal aquaculture.

2. ENVIRONMENTAL INTERACTIONS OF COASTAL AQUACULTURE

2.1 Degradation of Coastal Environments and Potential Effects on Coastal Aquaculture

In many coastal areas, pollution and habitat modification stemming from human activities other than aquaculture are increasingly affecting resource use productivity of aquaculture as well as limiting success and development possibilities of the aquaculture industry.

High organic and microbial loading in sewage discharged from densely populated urban and resort areas can contaminate cultured shellfish theret, rendering this aquaculture produce unsuitable for humans, particularly if consumed raw or partially cooked.

Heavy metals found in industrial effluents may be found in the animals cultured in the receiving waters. Potentially hazardous substances include mercury, cadmium, lead, copper and arsenic.

Serious oil spills can cause large-scale fish kills, and obvious effects on aquaculture include the contamination of farming structures and tainting of farmed organisms.

High levels of pesticides stemming from agricultural run-off, can be lethal to cultured organisms, while lower doses are believed to produce sublethal effects such as pathological changes in various organs.

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[1] Source: Guidelines for the Promotion of Environmental Management of Coastal Aquaculture Development. FAO Fisheries Technical Paper, No. 328. Rome, FAO. (in press)

[2] Note: These notes represent a brief summary of parts of above publication. They represent the views of the author and are not necessarily those of FAO.

The release of inorganic and organic nutrients into marine ecosystems can cause hypernutrification, and possibly phytoplankton blooms. Cultured fish can be killed by algal blooms through sudden water quality deterioration (suffocation due to gill damage and/or oxygen depletion) after collapse and decomposition of a bloom. In particular, bivalve culture is facing serious problems associated with the increasing occurrence of toxic phytoplankton blooms caused by a relatively small number of algal species producing a range of toxins, the effects of which include mortality of cultured stocks, as well as human illness and even death after consumption of contaminated bivalves

2.2 Potential Adverse Ecological Effects of Coastal Aquaculture

a) Nutrient and organic enrichment

Many aquaculture operations invariably result in the release of metabolic waste products (faeces, pseudo-faeces and excreta) and uneaten food into the aquatic environment.

The release of soluble inorganic nutrients (nitrogen and phosphorus) has the potential to cause nutrient enrichment (hypernutrification) possibly followed by eutrophication (increase of primary production) of a waterbody. Related changes in phytoplankton ecology may result in algal blooms, which can be harmful to wild and farmed organisms.

The largest proportion of solid wastes released, which is predominantly organic carbon and nitrogen, settles to the seabed in the immediate vicinity of the farm. Organic enrichment of the benthic ecosystem may result in increased oxygen consumption by the sediment and formation of anoxic sediments, with, in extreme cases, outgassing of carbon dioxide, methane and hydrogen sulphide; enhanced remineralization of organic nitrogen and reduction in macrofauna biomass, abundance and species composition.

There is evidence of very localized effects of reduced concentrations of dissolved oxygen in bottom and surface waters close to farm sites which are due to the considerable biochemical oxygen demand of released organic wastes and the respiratory demands of the cultured stock.

b) Degradation of wetland habitats

Coastal wetlands such as mangrove swamps are amongst the most productive ecosystems sustaining the ecological integrity and productivity of adjacent coastal waters, and are important breeding and nursery grounds for many commercially exploited fish and shellfish species. Several tropical countries have lost extensive mangrove areas due to clearing and conversion to fish and shrimp ponds, often accompanied by salinization and acidification of soils and aquifers.

c) Use of chemicals

A variety of chemicals are used in coastal aquaculture. These include: therapeutants, disinfectants, anaesthetics, biocides, hormones and growth promoters to control predators, prevent and control diseases and parasites and to alter sex, productive viability and growth of cultured organisms. Current concerns centre on: the longevity of bioactive compounds in animal tissues, the fate and effect of these compounds or their residues in the aquatic environment (e.g., toxicity to non-target organisms) and the stimulation of antibiotic resistance in microbial communities.

d) Biological interactions

The introduction and transfer of species and breeds for aquaculture purposes may alter or impoverish the biodiversity and genetic resources of the marine ecosystem through interbreeding, predation, competition, habitat destruction and, possibly, through the transmission of parasites and diseases.

Large-scale cultivation of bivalves in coastal embayments can interact with the marine food web by substantial removal of phytoplankton and organic detritus, as well as by competing with other planktonic herbivores.

Diseases may occur since many aquaculture practices and conditions around aquaculture operations can be stressful to the farmed stock. Stress increases susceptibility and predisposition to infectious diseases. Certain water quality conditions enhance virulence of potential pathogens. In the presence of stress and the appropriate pathogen, disease outbreaks can ensue.

2.3 Self-Pollution in Coastal Aquaculture

It is often coastal aquaculture itself which is affected by ecological changes deriving from farming practices. For example, water currents may be reduced significantly due to farm structures (cages, pens, rafts, etc.), which may lead to increased deposition and accumulation of organic wastes underneath or around the farming unit, increase in siltation and water quality deterioration (e.g., increase in turbidity due to high content of suspended matter). In addition, oxygen supply may be reduced, and outgassing of hydrogen sulphide and methane from bottom sediments may occur which will further affect growth performance and increase susceptibility to disease.

Pond culture which relies on tidal flow or pumping for water exchange may also face a steady increase of water quality deterioration. For example, total water exchange requirements of intensive shrimp pond systems will often exceed the flow rate of the tidal creek that serves as the supply canal and drainage ditch. The net result is that instead of replacing waste with clean water, these farms are very often recycling waste water. Extensive culture systems relying on the natural productivity of waters used may reduce or deviate water flow through farming structures and heavy siltation, thereby reducing the availability of food and nutrients.

Chemicals used may also present a potential risk to cultured organisms and may result in contamination of aquaculture products which reduces product quality and consumer acceptance. The development of drug-resistant pathogens, resident (and possibly dormant) both within and around the farming unit, may have serious negative feedback effects on farm productivity. The over-use of chemicals in hatcheries may result in reduced fitness, poor growth and decreased survival rates during the grow-out phase. Pond soils may be rendered less suitable by excessive chemical treatment.

The magnitude of negative ecological feedback effects of coastal aquaculture practices may increase with expansion and/or intensification. An increase in the acreage and/or number of farming units (ponds, racks, rafts, cages, etc.) and farms may be followed by deterioration of required environmental quality within and beyond the aquaculture area.

As a result of expansion of farming systems relying on naturally available food and nutrients, the natural productivity of waterbodies in coastal areas may be exhausted. Large-scale coverage and degradation of tidal habitats, including mangrove areas, may also affect wild seed supply. Aggregations of farms will exhibit cumulative effects of waste release and increased oxygen demand. Negative feedback effects of siltation, turbidity, build-up of organic-rich sediments, hypoxic or anoxic bottom waters, toxic outgassing, spread of diseases, etc., may then affect all farms in the area, particularly when located in sheltered and shallow coastal embayments with low water exchange rates. Land-based farming systems have faced similar problems, in particular when farms are clustered on suitable sites which resulted in very serious self-pollution problems.

2.4 Social Implications of Coastal Aquaculture Developments

The environmental impacts of and on coastal aquaculture may have serious adverse socio-economic and human health implications.

Large-scale mangrove conversion for shrimp and fish farming in Latin American and Asian countries in some cases has affected rural communities which traditionally depended on mangrove resources for their livelihood. The expansion of shrimp mariculture into mangrove habitat in some cases involved the transformation of a multi-use/multi-user coastal resource into a privately owned single-purpose resource. The costs of coastal ecosystem disruption for society included coastal erosion, saltwater intrusion into groundwater and agricultural fields, and a reduction in supply of a wide range of valuable goods and services produced from the resources available in mangrove forests or other coastal wetlands.

Some large-scale aquaculture enterprises displaced small-scale fishermen and aquaculturists. Competition for land and water resources also resulted in use conflicts sometimes with ensuing violence.

Several economic disasters due to significant aquaculture production losses have been attributed to self-pollution as well as to increasing coastal water pollution which fueled disease outbreaks and harmful phytoplankton blooms.

Consumption of raw and partially cooked shellfish grown in coastal waters receiving high organic and microbial loadings from urban sewage effluents can result in severe consequences for human health, including gastro-intestinal disorders, gastro-enteritis, infectious hepatitis, cholera and typhoid fever. Heavy metal pollution originating mainly from industrial discharges carries the risk of seafood contamination and human poisoning. Various forms of shellfish poisoning in humans such as PSP (paralytic shellfish poisoning), NSP (neurotoxic shellfish poisoning), DSP (diarrhoeic shellfish poisoning, ASP (amnesic shellfish poisoning) are occurring worldwide due to consumption of shellfish which accumulated phycotoxins stemming from toxic algal blooms. Effects of poisoning include gastro-intestinal disorders, respiratory paralysis, memory loss and death.

In summarizing, the potential negative implications of ecological degradation affecting directly or indirectly the socio-economic conditions within the environment of coastal aquaculture would include the following:

- decline in quality and quantity of food fish both cultured and captured,
- increased human health risks and reduced nutritional status,
- reduced consumer confidence and decreasing fish marketability within local, national and international environments,
- increasing resource-user conflicts and growing competition for markets and credits,
- decline and failures (collapse) of aquaculture enterprises and/or other fishery practices (e.g., artisanal fisheries) including the post-harvest sector, and
- social disruption within the rural environment following:
    - displacement of traditional community-based activities in agriculture, forestry and fisheries;
    - decreasing employment opportunities; shift towards unskilled and seasonal labour;
    - marginalization of resident resource-users and non-resource users due to increasing income distribution changes;
    - migration towards urban centres.

3. PLANNING AND MANAGEMENT MEASURES FOR ENVIRONMENTALLY-ACCEPTABLE COASTAL AQUACULTURE DEVELOPMENT

There is variety of activities which can be undertaken to promote environmental management of coastal aquaculture and to achieve its succesful development. Some general principles and policies are presented which may guide coastal aquaculture development planners in the implementation of possible management measures.

3.1 Some general principles and policies

General Principles

- Coastal aquacultu .ias the potential to produce food and generate income contributing to social and economic well-being.

- Planned and properly managed aquaculture development is a productive use of coastal areas which should be undertaken within the broader framework of integrated coastal area management plans, according to national economic objectives and national goals for sustainable development.

- The likely adverse consequences of aquaculture and other coastal developments on the social and ecological environment must be predicted and evaluated, and measures formulated in order to contain these consequences within acceptable, pre-determined limits.

- Aquaculture and other activities in coastal areas should be adequately regulated and monitored to ensure that adverse effects remain within pre-determined limits and to detect when contingency and other plans need to be brought into effect to reverse any trends which could lead toward unacceptable environmental consequences.

Policies

- The sound utilization of the ecological capacity of the coastal area to produce aquatic products and generate income.

- The development of policy and management mechanisms to reduce conflict with other coastal activities.

- The prevention or reduction of the adverse environmental impacts of coastal aquaculture and other coastal activities.

- The management and coordination of aquaculture activities to ensure that their adverse impacts remain within acceptable limits.

- The reduction of health risks from the consumption of aquaculture products.

3.2 Possible actions to enhance understanding of the interactions between coastal aquaculture development and the environment

Benefits

Emphasize the socio-economic and ecological benefits of coastal aquaculture. Collect and provide information on opportunities and achievements in coastal aquaculture development.

Adverse effects

Enhance awareness and understanding of the potential adverse environmental effects of coastal aquaculture. Address both the bio-physical and socio-economic aspects of environmental interactions associated with coastal aquaculture activities.

Distinguish between the species cultured, the farming methods applied and the prevailing ecological characteristics of the aquaculture site. Encourage research on ecological interactions of coastal tropical aquaculture.

Emphasize the risks of self-pollution and other negative feedback effects. In particular, address the self-pollution risks of increasing aggregation of aquafarms in coastal embayments.

Consider aquaculture as one of many activities in coastal areas. Multiple resource use in coastal areas in many cases results in serious pollution of coastal waters. Highlight possible threats to aquaculture due to increasing pollution in coastal areas.

Address potential negative social implications of aquaculture and other developments, in particular human health risks, resource use conflicts and possible marginalization of low-income groups.

Factors

Determine the factors affecting environmental compatibility of coastal aquaculture in your project or country. Specify causes of environmental mismanagement and constraints to sustainable development of coastal aquaculture.

3.3 Possible actions to properly assess environmental hazards and impacts of coastal aquaculture

General

Assess the capacity of the coastal ecosystem to sustain aquaculture development with minimal ecological change.

Pollution assessment / monitoring methods

Promote understanding of the environmental capacity concept. Encourage application of coastal pollution assessment methodologies such as the hazard assessment approach and adequate monitoring schemes.

Apply, where possible, pollution assessment methods which are specific to aquaculture. Ensure their appropriate use based on proper understanding of their applicability and limitations. Encourage further development of assessment methods suitable to aquaculture practices and ecological conditions in tropical environments.

Integrate aquaculture-specific monitoring schemes into existing coastal water pollution assessment activities. Select appropriate monitoring parameters and suitable sampling stations.

Employ remote sensing techniques and geographical information systems (GIS) to assess large-scale spatial and temporal environmental changes due to aquaculture and other developments in coastal areas.

Implementation of EIA

Enhance awareness on advantages and limitations associated with the implementation of environmental impact assessment (EIA) procedures.

Consider that assessment studies on the social and economic impact of development activities may be carried out separately or as an integral part of an EIA. Both types of impact assessments are essential when formulating coastal aquaculture programmes and projects.

Select an appropriate EIA sequence according to prevalent environmental and development requirements and according to the availability of information and implementation capacities.

Apply the EIA process to all major aquaculture development proposals. Provide information to applicants/developers on options for mitigatory and adaptive measures to be included in project proposals.

Incorporate EIA into integrated coastal area management strategies.

3.4 Possible actions to improve environmental management of coastal aquaculture development

General

Select and implement environmental management options which suit the specific requirements for environmentally-acceptable development of aquaculture and other activities in coastal areas.

Environmental protection

Improve/develop, where required, planning and management processes for protection of coastal environments.

Integrated coastal area management (ICAM)

Participate in the formulation and implementation of integrated coastal area management (ICAM) plans. Provide aquaculture-specific information required for ICAM. Indicate goals and set priorities for coastal aquaculture development. Identify coastal resource use conflicts between aquafarmers and other coastal resource users.

Participate in ICAM zoning activities leading to the designation of coastal resources and space. Indicate coastal areas suitable for aquaculture development possibly based on aquaculture-specific site selection surveys.

Encourage broad participation and consultation of all coastal resource users and stakeholder in formulation and implementation of ICAM plans.

Improve cross-sectoral communication and cooperation, possibly by establishing an institutionalized coordination office or cooperation network.

Help to ensure long-term funding for ICAM, through durable commitment of parties involved in aquaculture and their enforcement of aquaculture-specific regulations adopted.

Environmental legislation

Promote flexible and specific legislation in support of aquaculture development.

Environmental legislation should ensure accessibility and environmental protection of areas and resources required for coastal aquaculture development. Consideration of the variety of aquaculture practices and diversity of environmental settings is essential.

Help to formulate constructive environmental regulations for coastal aquaculture, where necessary, such as requirements for EIA, waste discharge limits and waste treatment specifications. Apply incentives and deterrents to reduce environmental hazards due to aquaculture activities.

Adopt and apply the EIFAC/ICES codes of practice on introductions and transfers of marine and freshwater organisms. Movement of species from and to aquaculture sites should be controlled through inspection and certification.

Coastal aquaculture products should conform with safety standards for seafood before they are offered for human consumption. Establish quality control measures for aquaculture products. Control the use of aquaculture chemicals such as antibiotics and pesticides.

Planning and management of coastal aquaculture development

Formulate/improve coastal aquaculture development and management plans.

Strengthen sectoral capacities for adequate coordination of coastal aquaculture development efforts. Help to ensure continuous and well-targeted support to coastal aquaculture development.

Co-operate with national development planners to ensure proper integration of coastal aquaculture development objectives and plans into national programmes for economic and agricultural development as well as environmental protection.

Environmental farm management

General

Promote environmental management at farm or project level. Consult with aquafarmers on specific environmental problems and mitigatory measures adopted. Provide opportunities for exchange of related experiences. Provide information and training to aquafarmers on options for improved environmental farm management.

Help to improve current aquaculture practices in terms of adequate site selection, efficiency in farm operation and maintenance, and continuous monitoring of biological and hygienic conditions on the farm. Avoid over-stocking.

Improve formulation and appraisal of coastal aquaculture development projects.

a) Use of mangrove wetland

Discourage, where possible, the use of pristine mangrove wetland for aquaculture. Provide instructions governing the use of mangrove wetlands.

b) Use of feeds and fertilizers

Improve on-farm feed management. Improve fertilization and feeding strategies. Avoid over-use of fertilizers and feeds. Adapt feeding practices to specific feeding habits and behaviour of the species cultured with due consideration of water quality and water movements in the farming unit. Monitoring of feed application and, where possible, feeding response of cultured stock is essential.

Continue research efforts on pond metabolism. Encourage development of diets and feeding methods adapted to requirements of semi-intensive farming systems in developing countries.

Continue efforts to improve physical and nutritional properties of manufactured feeds for use in both warmwater and coldwater aquaculture. Special emphasis should be given to applied research on dietary nutrient requirements of warmwater fish and shrimp species.

c) Waste management

Develop low-cost waste treatment technology for use in intensive land-based coastal aquaculture in developing countries.

Promote integrated polyculture practices to reduce waste loadings.

Explore ecological and economic feasibility of site rotation.

d) Chemical usage

Avoid usage of hazardous chemical substances. Emphasize measures to prevent water-quality deterioration, disease outbreaks and pests. Detailed on-farm record keeping on chemical usage is essential.

Discourage prophylactic use of antibiotics. Reduce environmental risks through minimal and alternating application of drugs.

Establish, where needed, aquaculture health management services to cover requirements for quarantine, diagnosis, treatment, monitoring and product quality control.

Control market availability of potentially hazardous chemicals through registration and licensing. Aquafarmers must be provided with comprehensive information on environmental risks and appropriate use of chemicals.

e) Contamination of aquaculture products

Promote further development of economically viable methods for depuration/sanitation of contaminated shellfish products. Monitor contaminant levels in shellfish grown in areas subject to pollution and blooms of toxic algae.

Prepare contingency plans for aquaculture areas threatened by events of harmful algal blooms, and advise aquafarmers on possible countermeasures to reduce risks of damage to cultured stock.

Promote aquaculture production in unpolluted waters and low risk areas. Increase public awareness of the safety aspects of consuming seafood. Apply, where unavoidable, temporary bans on harvesting or marketing of contaminated shellfish.

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21 October 1992

TECHNISCHE HOGESCHOOL DELFT

BOUNDARY CONDITIONS
for the use of
DREDGING EQUIPMENT
i82 A+B

by
Prof.ir. J. DE KONING
"Technology of Soil Movement"

LABORATORIUM VOOR
DE TECHNIEK VAN HET GRONDVERZET

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"Technology of Soil Movement"

DELFT UNIVERSITY OF TECHNOLOGY
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INTERNATIONAL INSTITUTE FOR HYDRAULIC AND ENVIRONMENTAL ENGINEERING.
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F O R E W O R D

This systematic classification of dredging activities has been crystallized from my experience in lecturing for the International Courses in Hydraulic Engineering in Delft during the years 1964 - 1984 and at the Delft University of Technology from 1978 to 1984.

I should like to record my appreciation of the assistance of ir. K.Oterdoom, Chief Scientific Officer in the Faculty of Civil Engineering of the Delft University of Technology, who read the manuscript and advised on the translation of the dredging terminology into English.
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Prof.ir. J. DE KONING

DELFT, april 1984.

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I. DEFINITION

Dredging is earth-moving carried out under water and/or earth-moving carried out by floating equipment.

II. TYPES OF DREDGING

II-1 Dredging in cut

The required work is the cut (harbour basins, canals etc.)
The resulting spoil has to be carried off.

II-2 Dredging in fill

The required work is the fill (dike, road-bed, reclamation etc.)
The soil needed has to be borrowed from somewhere and brought to the site.

II-3 Combination of cut and fill

The required work is a combination of cut and fill (e.g. harbour-basin with reclaimed building site around).
The soil from the cut is used for the fill.

II-4 Maintenance - Dredging

The required work is the removal of soil deposited in an earth-construction in cut after the construction has been made by nature or by dredging.
The resulting spoil has to be carried off.

II-5 Mining

The required work is the removal of overburden and the dredging of the mineral rich formation. Concentration of ore can take place on board or/and ashore.

III. ANALYSIS OF A DREDGING CYCLE

III-1 Disintegration of the soil

III-2 Digging

III-3 Reaction-forces counteracting the dredging forces (anchorage etc.)

III-4 Vertical transport

III-5 Loading into the means of transport

III-6 Acceptance by the means of transport

III-7 Spillage of spoil

III-8 Classifying improvement of the quality of the spoil or the slurry

III-9 Horizontal transport

III-10 Discharge into the dump-area (underwater)

III-11 Discharging in the fill

III-12 Compacting and shaping

III-13 Protection against external forces

III-14 Return of discharge-water

III-1 DISINTEGRATION OF THE SOIL

III-1.1 Chemically = blasting with explosives (rocks or rocky soil)

III-1.2 Mechanically = cutting, chipping, ripping

cutting edge, chisel, ripper (highly compact soil, e.g. heavy clay)

III-1.3 Hydraulic erosion = washing off

draghead of a trailing hopper suction dredger, water-jet (e.g. sand, soft clay, silt)

III-1.4 Disturbance of equilibrium (Under-cutting) =

earth slides - flow slides, plastic flow (all types of soil except hard clay and rock)

By means of mechanical digging, hydraulic erosive undermining, vibration or shaking, and surcharge.

III-2 DIGGING

III-2.1 Mechanically:

dipper, bucket, grab, blade

III-2.2 Hydraulically :

suction head of a suction pipe by means of the thrust of the fluid.

III-3 REACTION FORCE AS OPPOSED TO CUTTING AND DIGGING FORCES, NAUTICAL AND WEATHER FORCES

III-3.1 Horizontally:

anchors, cables, winches, spuds, thrust of ship propellors.

III-3.2 Vertically:

wires - chains - ladder winch - buoyancy of the ship - lifting wire - lifting winch - weight of digging device (grab) - weight of the ladder.

III-4 VERTICAL TRANSPORT

III-4.1 Mechanically:

grab
dipper
bucket
Archimedean screw
Jacob's ladder

III-4.2 Hydraulically:

suction pipe
(thrust of the liquid)

III-5 LOADING INTO THE MEANS OF TRANSPORT

III-5.1 For floating transport

III-5.1a Spoil with high concentration

directly dipper
grab

via chute ——— bucket

III-5.1b Spoil with low concentration

lander of a hopper suction dredger
spreader barge loading suction dredger

III-5.2 For continuous transport

III-5.2a Spoil with high concentration

belt-conveyor - trough with dewatering equipment
chute - feeder
vibrating chute - feeder with dewatering equipment

III-5.2b Spoil with low concentration

floating pipeline - shoreline)
side boom) by means of a dredgepump
submerged pipeline - shoreline)

III-6 ACCEPTANCE BY THE MEANS OF TRANSPORT

III-6.1 With mechanical supply (dipper, bucket, grab)

- no special problems in the case of barges or hoppers
- feeders and dewatering mechanism in the case of conveyor belts.

III-6.2 With hydraulic supply of spoil

- for holds of barges or hoppers, special devices to help settling of the particles and to limit overflow losses
- for pipeline transport, no special measures.

III-7 SPILLAGE OF SPOIL

III-7.1 Owing to the breaking-down of the grain-tension or the cohesion of the soil (suction cutter dredger, suction dredger, bucket dredger, dipper dredger etc.); slides of the bank

III-7.2 Owing to the discharging of the means of dredging (bucket, dipper, grab)

III-7.3 Owing to the overflow of the barges or hoppers (overflow losses)

III-7.4 Owing to the return flow of the polluted dredge-water.

III-8 CLASSIFYING- IMPROVEMENT OF THE QUALITY OF THE SPOIL OR THE SLURRY

III-8.1 Hydraulically

Overflowing of barge or hopper- desilting
Settlement in settling tank or with hydro-cyclones (reduction of overflow-loss)
Dewatering systems.

III-8.2 Mechanically

Vibrating screens (e.g. dewatering screens)
Shaking screens (gravel reclamation)
Crushers

III-9 HORIZONTAL TRANSPORT

III-9.1 Sailing

Suction barge (dumb or self propelled)
Bottom door dump barge " " " "
High door dump barge " " " "
Suction dump barge " " " "
Split dump barge " " " "
Tip barge " " " "
Deck barge " " " "
Sea-going hopper barge (self propelled)
Hopper grab dredger (self propelled)
Hopper suction dredger (self propelled)
Trailer (trailing hopper suction dredger)

III-9.2 Mechanically (direct or after possible discharge of the barge by an elevator)

Belt-conveyor
Rope way
Railway
Road transport

III-9.3 Hydraulically (pipeline- two-phase flow)

Barge unloading dredger (Rehandler)
Reclamation dredger (suction dredger with floating pipeline and shoreline)
Cutter suction dredger (with floating pipeline and shoreline)
Hopper suction dredger (self unloading)
Trailing hopper suction dredger (via pipeline)

III-10 DISCHARGE INTO THE DUMP AREA-(UNDERWATER)

III-10.1 Bottom discharge

With auxiliary equipment (dump-barge, high door dump-barge, split dump-barge)

By own means (hopper grab dredger, hopper suction dredger, trailer)

III-10.2 Mechanically

By grab crane
By scraper installation

III-10.3 Hydraulically (by dredge pump via pipeline)

Self-unloading trailer or hopper suction dredger
Suction dredger with floating pipeline and shoreline (Reclamation dredger)
Cutter suction dredger with floating pipeline and shoreline
Dustpan dredger
Side boom dredger (trailer hopper suction dredger with suspended discharge pipe)

III-11 DISCHARGING IN THE FILL

III-11.1 Mechanically (dry dumping)

Bulldozer
Dragline
Frontloader
Wheel-loader
Scraper
Lorry
Scraper installation
Shift conveyor belt - distribution belts

III-11.2 Hydraulically (wet dumping)

Various pipelines via Y-valves
Periodical lengthening of the pipelines
Embankment of dumping area by means of bunds
Regulation of the mixture-flow and maintenance of bunds by bulldozers, draglines, wheel-loaders etc.
Discharge of dredge water via weir-boxes, gates, pumping stations and syphons.

III-12 COMPACTING AND TRIMMING, SHAPING OF THE RAISED AREA

III-12.1 Hydraulically

The result is strongly dependent on type of soil.
Well graded sand gives the best possible compaction on a hydraulic reclamation area.
Hydraulic contouring is possible on wide even dumping areas.
Slopes and detailed dressing are done mechanically.

III-12.2 Mechanically

Dry, high and narrow hydraulic dumping sites are trimmed and compacted by bulldozers and/or draglines.
Other compaction equipment:

- rollers
- lorries
- vibrators.

III-13 PROTECTION OF EARTH WORKS AGAINST EXTERNAL INFLUENCES

III-13.1 Currents, wave action, ship's waves, propeller splash

Fascine mattresses, fascine collars, sheet piles, retaining walls, enrockments, stone lining, grassing, asphalt lining, filters, air vents etc.
For temporary work, sand may sometimes be kept in place by well points.

III-13.2 Wind erosion

Bundles of straw stuck in the soil to prevent blowing away, straw mattresses, top soil, grassing, turfing, spraying (chemical products).

III-13.3 Traffic influences

Side walks, road surfaces, runways, road-durface constructions.

III-13.4 Rainwater

Camber, slopes, side drains, drainage.

IV CONDITIONS INFLUENCING THE CHOICE OF WORKING METHOD AND EQUIPMENT

IV-1 Scope of the work as regards quantities and transport distance.

IV-2 The capacity required in relation to available time and funds and the economical aspects of the work to be made.

IV-3 Accessibility of the site for the equipment.

IV-4 Vegetation or cultivation to be preserved or removed.

IV-5 Type of soil to be removed or handled.

IV-6 The availability and quality of borrow areas for reclamation material and/or dump areas for disposal of spoil.

IV-7 The possibilities for the discharge of diluting water.

IV-8 Water and weather conditions.

IV-9 Soil transport on bottom and silting-up.

IV-10 Dimensions: length - width - height - depth.

IV-11 Horizontal and vertical tolerances required.

IV-12 The stability of the completed work and its immediate surroundings.

IV-13 Horizontal and vertical transport distances.

IV-14 Transport tracks and transport possibilities over water and over land.

IV-15 Possibilities for and problems of anchorage.

IV-16 Hindrance by and to shipping.

IV-17 Danger or hindrance to surroundings.

IV-18 Pollution of the surroundings area.

IV-19 Availability of equipment.

IV-20 Feasibility of and time required for mobilisation and demobilisation of equipment.

IV-21 Method of quantity survey (in cut; in fill; in means of transport)

IV-22 Energy supply.

EXPLANATION OF CONDITIONS MENTIONED

IV-1 SCOPE OF THE WORK AS REGARDS QUANTITIES AND TRANSPORT DISTANCE

The scope of the work is a very important factor for defining the capacities of the equipment required. Consideration of the proportion of the cost of mobilisation and demobilisation against the cost per cubic metre to be handled is often determinant.

IV-2 THE CAPACITY REQUIRED IN RELATION TO AVAILABLE FUNDS AND THE ECONOMICAL ASPECTS OF THE WORK TO BE MADE

Limitation of periodically available funds may cause restricted production and consequently may have an unfavourable effect on the price. On the other hand it is possible that in the event of a forced production the price per m^3 may work out higher but at the same time would be justified by completion of the work ahead of schedule.

IV-3 ACCESSIBILITY OF THE SITE FOR THE EQUIPMENT

It is natural that, for example, in the case of a large work situated along a major waterway completely different machinery would be required than for a similar work which could only be reached via minor waterways or even exclusively over land.
As a result of this problem the use of dredging equipment which can be transported by boat or train has increased considerably.

IV-4 VEGETATION OR CULTIVATION TO BE PRESERVED OR REMOVED

Vegetation may strongly influence the type of equipment to be used. If, for instance, one has to dredge in a swampy mangrove area, a suction cutter dredger or bucket dredger cannot immediately be put into operation.
First the trees and their roots would have to be removed from the soil. The time needed for this determines the time required for the actual dredging etc. that is to follow.
Preservation of the vegetation or cultivation may also influence the sailing or pumping distances.

IV-5 TYPE OF SOIL TO BE REMOVED OR HANDLED

This is the most important factor for determining the working method and the equipment to be used.
It strongly influences the production of all equipment and, in most cases, a variation in production rate of the ratio 1 : 10 is possible if one compares the most difficult conditions with the easiest ones.
In chapter III the dredging cycle has been analysed into 13 items.

Each of these 13 items is strongly influenced by the type of soil to be handled.

In particular, the following points are very important as regards the production which may be achieved:

III-1 Breaking of the structure of the soil (degree of hardness and cohesion, internal friction and oxygen content).

III-2 Excavation

III-4 Vertical transport

III-6 Intake by transport means - overflow-losses during the loading, dependent upon grain size.

III-7 Spillage of spoil in relation to cohesion, adhesion and grain size

III-9 Horizontal transport, depending on degree of disintegration in the cutter head and in the sand pump of clay, grain size of sand and gravel, volume weights and specific gravities.

Dredged soil can generally be classified as follows:

IV-5.1	Rock formations	- rock - coral
IV-5.2	Cohesive soil	- clay - peat
IV-5.3	Non-cohesive soil	- silt - mud - sand - gravel
IV-5.4	Old constructions and "dirt"	- debris - stone facing - fascine mattresses - light rubble stones - heavy rubble stones - concrete blocks - ships' wrecks - wooden and concrete piles - various articles such as beds, bicycles and wheels etc. - explosives

For dredging purposes a more specified classification of rock and soil varieties has been published by the "International Association of Dredging Companies",P.I.A.N.C., (Stockholm 1972).
From the foregoing it is evident how important it is to prepare a dredging schedule in order to carry out an accurate test-boring programme in combination with a laboratory study of the soil samples.

IV-6 THE AVAILABILITY AND QUALITY OF BORROW AREAS FOR RECLAMATION MATERIAL AND/OR DUMP AREAS FOR DISPOSAL OF SPOIL

IV-6.1 The choice of the borrow pit is determined mainly by the quality of the spoil (mostly sand for reclamation and boulder clay for bunds and protection).

IV-6.2 Location in relation to the work is also very important . Since about 1950 it has been a normal practice in the Netherlands, when building roads or extending towns, to choose sand pits halfway the road-stretches close to the construction site. After cutting away the upper layer with a demountable cutter suction dredger the sand is dredged from the pit with a demountable suction dredger and pumped to the site via a floating discharge line connected to a shore pipeline.

IV-6.3 If excavation of local pits is not feasible or desirable, the most important factors would be the access to the pit for floating equipment and the distance between the pit and the site. Whether or not the construction of a shiplock is economically justified depends on the size of the pit and its maximum capacity. The economical sailing distance depends mainly on the size of the waterway and the quantity to be transported weekly.
For the past few years the administration in the western part of the Netherlands has changed her policy regarding borrow pits and has concentrated on a number of very large "natural" sources from which sand can be obtained for years to come, either under private or government management. The most important of these sand-sources are:

With horizontal transport by barges:

In the southern part of the Netherlands:

the Zeeland estuary (Rotterdam)

In North-Holland:

Spiegelpolder, Wijde Blik, IJsselmeer (Amsterdam)

With horizontal transport through long pipelines:

In North-Holland:

Vinkeveense Plassen (Amsterdam)
IJsselmeer (Amsterdam)

The most recent development in this field is borrowing of sand on a large-scale from the North-Sea approx. 20 km off-shore. (Rotterdam, Amsterdam).

IV-6.4 The winning of clay and boulder clay has a more local character although in some cases the shipping distances are still considerable (Zuiderzee works: boulderclay pit near Urk; Delta works: clay-pit near Numansdorp). The development of lining dikes and dams with asphalt has decreased the demand for boulder clay and clay-pits.

IV-6.5 The transportation of the spoil from a dredging work in cut, also creates many problems and can determine the price of a specific work and the choice of the transport means.

In a densely populated country such as the Netherlands space is limited and often large distances have to be covered with auxiliary equipment, e.g. barges etc. Old sand or gravel pits and deeper places in the river bed are often used as storage reservoirs. If these are not available within an economically justified distance, it is necessary to use dump sites ashore. A fact to be considered when working at sea is to determine how far away dumping should take place in order to ensure that the material will not flow back. Sometimes the acceptance of a certain degree of silting up and the consequential additional dredging work might prove cheaper than disposal of all the spoil further away to avoid the risk of returning material.

IV-7 THE POSSIBILITIES FOR THE DISCHARGE OF DILUTING WATER

IV-7.1 Occasionally the reclamation area is above the level of the main dewatering channel, lake or sea. In that case the diluting water may be disposed of through a discharge gate built into the bund dikes protecting the dumping area. Spillage of spoil or silt into the dewatering channel in which the water is discharged are normal problems and additional dredging may be necessary, for instance to maintain the depth of the waterway.

IV-7.2 Where the dumping area is lower than the surrounding waterlevels, a pumping station will be necessary to pump the superfluous water into the dewatering channel through a pipeline.

IV-8 WATER AND WEATHER CONDITIONS

These determine:

IV-8.1 The available working time in view of the necessity to keep the equipment for the disintegration of the soil and the digging means in contact with the bottom, such as dippers, grabs, cutters, suction pipes, trailheads etc.

IV-S.2 The available working time in view of anchorage problems in bad weather, breaking adrift from anchors, bending or breaking of spuds.

IV-S.3 The manoeuvrability (strong side wind and heavy current entering at a specific angle, etc.) which is important for the dredging to grade the cut.

IV-S.4 The available working time with regard to mooring and stability of barges alongside in the event of currents and/or high wind velocities and waves.

IV-S.5 The available working time in respect of the stability of the discharge equipment, such as floating pipelines and conveyor belts.

IV-S.6 Problems of slamming bottom doors of sea-going hopper barges and jumping suction pipes of hopper suction dredgers.

It is difficult to give definite figures but the following can be considered as a general indication for maximum wave height:

Short waves

small equipment discharging into barges	0.3 to 0.5 m
large equipment discharging into barges	0.5 to 1.0 m
small equipment with floating pipeline	0.2 to 0.5 m
large equipment with floating pipeline	0.5 to 1.0 m
self-propelled barges with suction pipe	0.6 to 1.0 m
trailer with swell compensator	2.0 to 4.0 m

Long waves

small equipment discharging into barges	0.2 to 0.4 m
large equipment discharging into barges	0.4 to 0.8 m
small equipment with floating pipeline	0.2 to 0.5 m
large equipment with floating pipeline	0.3 to 0.6 m
self-propelled barges with suction pipe	0.4 to 0.8 m
trailer with swell compensator	2.0 to 4.0 m

Current velocity

If the anchors do hold sufficiently, it makes a considerable difference as to whether the ship can work with the current or whether it has to work at an angle to the current, as for instance a cutter suction dredger.

For a cutter suction dredger the situation is particularly dangerous when the current is directed against the ladder side. After a certain velocity the winch strength will not be sufficient to bring the ship back to mid-stream; the dredger will then swing round her spud and this may cause a lot of trouble (the floating pipeline might be damaged, the spud might break or slip by the shock etc.)
In that case a timely stopping will be necessary. This will also have the effect that pipeline becomes empty so that the floats will rise as high above the water level as possible and consequently be less affected by the current. For most of the larger cutter suction dredgers the safe limit can be estimated at approx. 2 knots velocity of the current.
For bucket dredgers and stationary dredgers the limit is approx. 3 knots provided the anchorage and freeboard of the ship are sufficient. When working in heavy currents self-propelled barges are preferable, as the mooring of dumb barges might give problems.

IV-9 SAND TRANSPORT ON BOTTOM AND SILTING-UP

This problem arises mainly in rivers, estuaries, coastal waters and harbour basins. The designer's main problem is where to locate the dump area for the spoil in order to prevent the dredged and dumped spoil from flowing back into the cut. It is extremely difficult to evaluate this quantitatively and it is consequently often very hard to make a choice when alternative lay-outs of channels are possible.

In consequence it is very important to obtain as much reliable information on this point is possible during the pre-design period. However, the possibilities to do so are as yet rather limited. Calculations based on pre- and post dredge surveys, lead - in the case of sand transport or siltation - to incorrect prices. In this respect measuring in the means of transport would probably give the best results.
Because fresh layers of silt are usually not very coherent, they are easily pumped and in that case the problem shifts to settling of the solids in the hopper.
(See III-6).
For trailers which pump very fine sand from harbour basins, it is common practice to accept the volume weight as given by the dredge pump. The system of overflow is not practised in this case.

IV-10 DIMENSIONS: LENGTH - WIDTH - HEIGHT - DEPTH

The dimensions often determine

IV-10.1 The type of machinery that can be used;

IV-10.2 The size of the machinery to be used;

IV-10.3 The number of units required to achieve the desired output.

The length is especially important for trailers as they need a long trailing length in order to operate economically. Trailing lengths shorter than 500 m in one direction, for instance, lead to a progressive decrease in production.

The width is particularly important in the case of swinging machinery such as bucket dredgers, dipper dredgers and cutter suction dredgers. The minimum width depends on the possibility to dredge the hull of the dredger and the auxiliary equipment free.

Generally it can be said:

Normal minimum cutting width on the water level:

Bucket dredger	: approx. 1.4 x length of the dredger
Dipper dredger	: pontoon width + 2 barge widths - 10 m
Cutter suction dredger	: length of dredger - raised ladder
Trailer	: 4 x length of dredger (possibility of swinging round); 2,5 x length of dredger when equipped with bowpropellor.
Suction dredger	: 300 to 400 m
Grab dredger	: pontoon width +10 m' if material is discharged on the site. Alternative: pontoon + 2 barges -10 m'.

Depth

a) Depth in dredging area: this is especially important for hopper suction dredgers and trailers as these have to pass, when loaded, over the area to be dredged.

For a small trailer : approx. 6 m)
For a medium trailer : approx. 8 m) + wave height
For a large trailer : approx.10 m)

b) The other machinery requires sufficient sailing depth to reach the site and the first cut must be sufficiently deep for:

1. draft
2. layer of spilled spoil under the ship
3. sufficient water depth under the bottom of the dredger to prevent the sand from entering the sea chests of the water pumps used for cooling the engines.

Consequently the minimum depth of the first cut by very small bucket dredgers or mini-cutter suction dredgers is approx. 5 m (low tide). These 5 mtrs. could increase to 8 meters if there was a high bank above the water level (e.g. 4 m bank above water level gives a 12 m cut; in the case of 25% spillage the water depth at the location of ship will be 5 m). This necessity has important consequences for dredging the side slope in steps.

In the case of a very high bank it is essential first to roughly dredge the slope and afterwards to re-dredge only the side slope (see fig. V-14). This re-dredging is an expensive operation and should only be requested if it is essential for the work.
For the dipper dredgers it will generally be sufficient, in cases of low tide, to have 1 m depth under the bottom of the pontoon. As the bucket can dig a forward cut above the water level and is hardly effected by collapse of the bank, the spillage will be far less than when using bucket dredgers or cutter suction dredgers.

c) Stationary suction dredgers require a deep bank as they depend completely on the breaking down of the bank by undermining. Minimum height of the bank: 10 m sand or gravel.
Usually a stationary suction dredger operates at a depth of 25 to 30 m causing the cone, from which the sand flows to the suction head, to be as large as possible (see figs. V-6.1.1, V-6.1.2, V-6.1.3).

<u>Height</u>

The influence of the height of the bank has already been discussed in the previous paragraphs.
Also of importance is: the height of obstacles which have to be overcome, for instance by means of pipelines or conveyor belts (hills and mountains) and the difference in height between suction pump and dumping area.

IV-11 HORIZONTAL AND VERTICAL TOLERANCES REQUIRED

Certain tolerances must be applied to a dredging project for different reasons:

IV-11.1 In relation to the quantity to be dredged and/or charged

IV-11.1.1 For weeks in cut

a. Vertical tolerance
This is the most important for a large wide channel (e.g. Hoek van Holland - IJmuiden). Spillage is an essential factor.

b. Horizontal tolerance
This is very important in cases of very narrow channels (e.g. trench for pipelines).

c. Slope tolerance
In this case the specific properties of the soil are very important in view of stability. Furthermore it may be very important whether the dredger is operating parallel to the slope or at an angle of 30°, which is for instance necessary when dredging a tunnel trench in a tidal area or in a river; the angle of the approach cut of, for example, a bucket dredger may then be the criterium (recent examples: Benelux tunnel (Vlaardingen) - Schelde tunnel (Antwerp)).

IV-11.1.2 For works in fill

a. Vertical tolerance
Mainly depends on the settling properties of the spoil and the subsoil. The final levelling is usually carried out by buildozers.

b. Horizontal and slope tolerances
When reclaiming an area the hydraulic filling is generally carried out in passes. For this reason the slopes are trimmed afterwards with "dry" equipment (mainly draglines) so that one can use the relevant tolerances.
In this case a problem relating to quantity hardly exists for low slopes. For technical reasons the slope is shaped with "dry" equipment (usually draglines) and in cases of slope heights of up to 2 m it is quite easy to see whether there is too much or too little sand.
A high slope is a completely different thing. It often happens that sand has later to be removed or added.

IV-11.2 In relation to aesthetical or technical requirements

IV-11.2.1 For works in cut

a. Horizontal tolerance
Here very strict requirements exist for narrow channels or canals. For very wide channels, for instance, a large nautical tolerance is required so that the specifications for the dredging tolerances can also be easier. Fairly strict tolerance requirements might result from the technical necessities of a straight retaining wall, quay-wall or slope in harbour basins and canals.
In cases of narrow trenches for caissons, pipelines etc. the sides of these constructions must naturally stay clear of the foot of the slope.

b. Vertical tolerance
Depth tolerance of waterways to prevent difficulties for the shipping traffic resulting from the depth of the channel. Generally this requirement is stricter for smaller inland waterways than for large shipping channels where tide, bedload, spoil transport, silting and salinity play an important part. For these waterways the choice of time for maintenance is often more important than the dredging tolerance itself. For the construction of canals or excavation works (e.g. tunnels) strict tolerances are demanded in connection with the sandfill in between the underside of the tunnel and the bed on which the tunnel is founded.

c. Slope tolerances

It makes a considerable difference whether the slopes are under or above the water level. The tolerance requirements on both these cases are of a different order.
For an underwater slope, stability and nautical requirements are decisive.
In the case of slopes extending above the water level a straight water-line will be required. Where a large tidal range exists this may be a very heavy demand, which can only be met by using special grading equipment "dry".
The fact that these slopes are often lined with dumped or set stones or covered with asphalt, also demands sharp tolerances, because it can become very expensive when the slope has to be finished to grade with the stones or the asphalt, starting from an inaccurate slope.

IV-11.3 Possible tolerances for various equipment when dredging in excavation

Deciding on the possible tolerance for the various machines is a very complex problem because of the large number of variables.

IV-11.3.1 The possible tolerance depends on:

a) the type and size of the equipment
b) the type and properties of the soil (hardness, compaction, cementation, cohesion etc.)
c) the prevailing waves (height - length - frequency)
d) the prevailing tide
e) the dredging depth in relation to the optimal position of the ladder
f) the experience of the personnel
g) the instrumentation on board the dredger
h) the method of position-finding
i) the degree of automation of the dredger
j) the quality of survey- and sounding work and the equipment used therefore.

IV-11.3.2 Quantitive information on normally realisable tolerances

In table IV-11.3.2 an attempt has been made to compile the relevant information in a scheme. However, this information is of such importance to the client as well as to the contractor that it would be useful to appoint a study commission who could draw up and be responsible for such a scheme. Misunderstandings and disputes would diminish if such a scheme was available, and at the same time it might have a stimulating effect on improving the dredging equipment. A good example of a recent improvement is the application of gyro-compasses on cutter suction dredgers.

TABEL IV–11.3.2 ROUGH TOLERANCE DATA FOR NORMAL PRODUCING DREDGERS

Nr.	Type of dredger	Size of the dredger	Rock				Not cohesive soil						Cohesiv[illegible]	
			Blasted rock		Weathered rock and softer stone		Boulders & cobbles		Gravel		Sand		Mud	
			T_H	T_V	T_H	T_V	T_H	T_V	T_H	T_V	T_H	T_V	T_H	T_V
V-1	Bucket dredgers	Volume of buckets 50 – 200 litre 200 – 500 - 500 – 800 -	N.A. 150 N.A.	N.A. 30 N.A.	N.A. 100 N.A.	N.A. 20 N.A.	N.A. ? ?	N.A. ? ?	50 75 100	20 25 35	100 150 200	30 50 60	75 125 150	[illegible]
V-2.1) V-2.2) [illegible])	Dipper dredgers Backhoe dredgers	Volume of bucket 0,5 – 2 m3 2 – 5 - 0,5 – 2 m^3	100 150 100	30 50 30	100 150 100	30 50 30	? ?	? ?	75 100 75	30 50 30	100 50 100	30 50 30	NA NA 75	[illegible]
V-3.1) V-3.2) V-4.1)	Floating grab-dredgers	Volume of grab 0,5 - 2 m3 2 – 4 - 4 – 7 –	100 200 250	50 75 100	100 200 250	50 75 100	? ? ?	? ? ?	75 150 200	50 75 100	100 200 300	30 50 75	N.A. N.A. N.A.	[illegible]
V-5	Cutter suction dredgers	Cutter ⌀ 0,75 – 1,50 1,50 – 2,50 2,50 – 3,50	N.A. 75 100	N.A. 25 30	N.A. 50 75	N.A. 20 25	N.A. N.A. N.A.		150 225 300	50 75 100	200 250 300	40 50 60	150 200 250	[illegible]
V-8	Seagoing hopper-dredgers	Hopper capacity 500 – 2.000 2.000 – 5.000	N.A. N.A.		N.A. N.A.		N.A. N.A.		500 1000	150 250	1500 2000	500 750	N.A. N.A.	[illegible]
V-9.1)	Trailing hopper suction dredgers	Hopper capacity in metric tons 500 – 3.000 ton 3.000 – 6.000 ton 6.000 – 18.000 ton	N.A. N.A. N.A.		N.A. N.A. N.A.		N.A. N.A. N.A.		1000 1500 1500		1000 1500 1500	25 50 75	1000 1500 1500	

T_H : horizontal tolerance in cm

T_V : vertical tolerance in cm

N.A. : not applicable

Slopes: When the actual angle of the slope is steeper than $tg\ \alpha : \frac{T_V}{T_H}$, the horizontal tolerance will be ruling

The vertical tolerance is ruling when the angle of the slope is more gentle than $tg\ \alpha : \frac{T_V}{T_H}$

SECTION 1

			Cohesive soil						Organic soil		Addition for tide per m² difference in waterheight	Addition for cross-current ± 1,5m/sec.		Addition for heavy wave-attack
	Sand		Mud		Hard clay		Soft clay		Peat					
T_V	T_H	T_V	T_H	T_V	T_H	T_V	T_H	T_V	T_H	T_V	T_V	T_H	T_H	T_V
[illegible]	100 150 200	30 50 50	75 125 150	15 25 30	50 75 100	10 15 20	75 125 150	15 25 30	75 100 125	25 35 45	5 cm² 5 5	50 75 100	25 50 75	15 25 35
	100 50 100	30 50 [illegible]	NA NA 75	NA NA 20	50 100 50	15 30 15	50 150 50	20 50 20	75 150 75	30 50 [illegible]	5 5 5	25 50 25	25 50 25	15 25 15
[illegible]	100 200 300	30 50 75	N.A. N.A. N.A.	N.A. N.A. N.A.	N.A. N.A. N.A.	N.A. N.A. N.A.	50 150 250	30 75 100	75 150 250	40 75 125	5 5 5	25 50 75	25 50 75	15 25 35
50 75 100	200 250 300	40 50 60	150 200 250	30 40 50	75 100 150	15 20 30	100 150 200	25 40 50	100 125 175	30 40 60	5 5 5	50 75 100	25 50 75	15 25 35
[illegible]	1500 2000	500 750	N.A. N.A.	N.A. N.A.	N.A. N.A.	N.A. N.A.	N.A. N.A.	N.A. N.A.	N.A. N.A.	N.A. N.A.	– –	– –	– –	– –
	1000 1500 1500	25 50 75	1000 1500 1500	30 50 50	N.A. N.A. N.A.	N.A. N.A. N.A.	1000 1500 1500	50 75 100	N.A. N.A. N.A.	N.A. N.A. N.A.	5 5 5	250 500 500	100 150 150	0 0 0

T_V, the horizontal tolerance will be ruling

T_H

re gentle than tg $\alpha = \frac{T_V}{T_H}$

? Depending on boulder and cobble size.

IV-11.4 Comparison of cost and tolerance requirements

This point plays a very important role if tolerance requirements exist because of the quantity of soil to be dredged.
In cases of well-defined tolerances, the quantity to be charged will decrease but the price per cubic metre will increase. E.g.: dredging of the slopes with a small bucket dredger to obtain the correct inclination is very costly extra work.
The question as to the most economic solution must remain constantly under observation.

IV-12 THE STABILITY OF THE COMPLETED WORK AND ITS IMMEDIATE SURROUNDINGS

The stability of the work may be endangered:

IV-12.1 In the event of excavation

a. Because of too steep a slope
This might occur in works where the dredging technique forces to undermine a high bank. Auxiliary dragline work or work with a machine especially equipped for such a job could become necessary if the problems become too difficult.

b. Because of erosion caused by a current which undermines the slope. The remedy is the use of fascine mattresses. The actual technique is outside the scope of dredging.

c. When pumping sand with a suction dredger it is necessary to remain a sufficient distance from the quays and buildings etc. which are to be saved. Of course, this depends on the depth of dredging. For the normal dredging depth of 30 m, the minimum distance is 150 m.
Thus the total width of a reclamation pit becomes important. For instance, a pit 400 m wide is very practical, whilst 300 m would be the minimum width. Should this width not be available, then the use of a cutter suction dredger would become necessary.

IV-12.2 In the event of a work in fill

When pumping spoil onto sites having a poor sub-soil, one of the most awkward side effects is sub-soil failure.
It can happen that the foundations of houses located more than a 100 m from the dumping site become damaged due to these failures. Reclamation with dry sand by lorries is a remedy. The consequences of a fall in sand levels in the fill area can be costly, when it is not economical to retract the pipeline to the subsided area. The missing sand must then be brought in by lorries or bulldozers.

IV-13 HORIZONTAL AND VERTICAL TRANSPORT DISTANCES

IV-13.1 Vertical transport

The aspect of excavation depth has been discussed under 10.3. The consequences with regard to the vertical transport are best analysed with the aid of chapter III-4.

III-4.1 Mechanically

For the grab and the dipper the dredging depth will influence production as regards the time needed per cycle.
The deeper the dredging, the less the production.
The grab is least subject to the maximum dredging depth. With the dipper dredger a greater depth could be achieved by using a smaller bucket with a longer stick and boom.
The limitation on production then doubles; a smaller bucket and more time per cycle.
For the bucket dredger one would reduce the number of buckets and replace them by links.
Various bucket dredgers have been reconstructed to make them suitable for deep dredging in tunnel pits.

III-4.2 Hydraulically

For dredgers with hydraulic vertical transport, the suction depth normally limited to 30 m can be increased, whilst maintaining the same output, by putting the dredge-pump on a ladder under water or by placing an ejector in the suction pipe.

IV-13.2 Horizontal transport

In cases of excavation as well as reclamation, the distances and conditions of transport are very important.
The means of transport are mentioned in III-9.

IV-13.2.1. Horizontal transport over a very short distance

This is practised in 4 cases:

a. If dredging is carried out in fast flowing water (river or sea-arm).
   In this case the dredger can dump the spoil sideways overboard into the river.

b. In cases of mechanical excavation by a bucket dredger through a so-called flow-chute which can have a length of 30 to 50 m. The spoil is pushed through the chute with water.

c. In cases of excavation by a suction dredger or cutter suction dredger through a short transverse floating pipeline.

d. In cases of excavation by a trailer through a transverse pipeline above the water (so-called "side boom dredger") (fig. V-10.1) which can be 50-75 m long.

In the case (a) further transport is performed by the river. This is only possible in instances of fine sediments (fine sand, silt). When digging or maintaining a canal, a bucket dredger with the above mentioned flow-chute can dump directly onto the bank inside earthen bunds built along the canal especially for this purpose.
During the last 10 years this system has been replaced by small cutter suction dredgers with floating and shore pipelines.

IV-13.2.2 Transportation over medium distances (up to 2000 m)

More and more cutter suction dredgers are being used for this work, especially in the case of a combined work (cut and fill). The normal pumping distance is 1500 to 2000 m for ordinary sand (200 μ - 1 mm).
When pumping silt or mud this distance could be twice as much, while for gravel it is limited to approx. 400 m. (In all cases pumping pressure is approx. 6 ato). If in the event of excavation an underwater dump area is available at a short distance (2 to 3 km), then a bucket dredger combined with dump barges can be used economically, particularly when handling soft clay and silt.
When such a dump area is a long distance away (e.g. 10 km) it is sometimes more economical to find a shore-site close by and to use hopper barges with the bucket dredger and pump the spoil ashore by means of a barge-unloading dredger (rehandler).
For carrying gravel over long distance, it is best to dredge mechanically (grab) and to transport by floating equipment and floating and shore conveyor belts. Hydraulic transport of gravel is generally uneconomical.

IV-13.2.3 Transport over a long distance (2 to 4 km)

This concerns particularly the field of floating transport. The most important secondary ships in this field are depicted in figs. V-13.1; V-14.1; V-15.1; V-16.1; V-17.1 and V-18.1.
The longer the haul the more justified it is to make the ships self-propelled. In cases of long hauls (> 20 km) sand transport by boat is being considered more and more and the use of hopper barges on which the skipper, his family and a deck hand can live is very much on the increase. On arrival at her destination the ship is unloaded by a barge unloading dredger which pumps the sand through a pipeline onto the site. For the transport of very large quantities of sand over a route which rarely changes, one may consider transport by means of a long pipeline having a number of booster stations.

Two of these long pipelines were installed near Amsterdam : one with a length of 12 km and with 7 pumps coupled in series and divided over 6 stations; the other having a length of 7 km, and 5 sand pumps also joined in series, divided over 2 stations. The investments involved in such installations are very high but the cost of transport can compete with floating transport + barge unloading dredger, particularly when the canal has limited dimensions and has many bridges and sluices.

IV-13.2.4 Vertical and horizontal transport for dredging in coastal waters and sea-arms

For working on the river slightly more inland, items IV-13.2.1; IV-3.2.2; IV-3.2.3 will apply.
For dredging in coastal waters item IV-13.1 is applicable for mechanical vertical transport with, say, a bucket dredger, a grab or dipper dredger.
For the usual equipment, such as a suction hopper dredger and trailer, there is also the interesting point of sand pumps built on the ship in the normal manner becoming further immersed under water when the hopper fills itself. This gives the same results as a suction dredger where the pump is placed on the ladder. Therefore no new problems arise with vertical transport, because the required new hopper dredgers which have to meet the latest demands for deepwater channels for supertankers (suction depth up to 30 m), have a large draft.

Horizontal transport

This mainly takes place afloat and it is often the dredger itself which handles the floating transport (see figs. V-4.1; V-8.1; V-9.1).
If a bucket dredger, dipper or grab dredger is operating, the sea-going hopper would be the means of transport. The shipping distance vary from 2 to 20 km. The ships must be completely seaworthy.
If the sailing distance is very long it might be considered to pump ashore the contents of a hopper dredger with its own pumps. However, this solution generally proves expensive because of the time it takes to couple the discharger of the hopper to the pipeline and to unload the hopper. It is often more economical to dump into an under-water surge-pit and to pump the spoil ashore by means of a special reclamation dredger. This type of working-system is generally economical only if a reclamation project is involved (for instance filling of an industrial site).

IV-14 ROUTES AND POSSIBILITIES FOR TRANSPORT OVER WATER AND LAND

The local topography of the work may vitally affect the choice of equipment.

If, for instance, a reclamation work is to be carried out at a distance of 40 km from the "wet" borrow-pit and there is neither a canal nor a road fit for lorries, then the following methods will have to be compared:

a. Reclamation by a suction dredger - drying up of the sand, loading into lorries, transport by lorry. Permanent investment: construction of a road of 40 km.

b. Reclamation by a suction dredger - floating pipeline, shore pipeline with 10 booster stations. Permanent investment: depreciation on pipeline and 10 booster stations.

Many possibilities can be considered. This example, however, makes it clear that such a comparison is essential for the choice of the correct equipment.

IV-15 POSSIBILITIES AND DIFFICULTIES OF ANCHORAGE

See figures V-1.3; V.2.4; V-3.11; V-3.2.1; V-3.3.1; V-5.3.1; V-5.3.2; V-5.3.3; V-6.2; V-8.2 and V-9.4. With these figures an attempt has been made to show how the cutting vacuum and digging forces are equilibrated by means of anchors and wires or chains, spud poles and the buoyancy of the ship itself.
If the anchorage is poor, it may happen that dragging results, which might cause a severe loss in production. In the field of anchoring a few additional measures are possible.

a. using anchor barges to increase the wire length, so that the absorption of the forces will be easier.

b. inserting or adding, say 100 m of heavy chain between anchor and wire rope.

c. application of anchors with large flukes, so-called Danforth anchors or polar anchors.

d. use of double anchors, i.e. two anchors in series with a length of chain in between.

e. use of very long wires to the shore fixed on to dead-man.

f. when spuds slip, anchor wires may be placed on starboard and port to provide increased holding strength

g. special anchor installations.

In the case of a cutter suction dredger the forward side wires can be re-positioned more frequently, so that there is less chance of them pulling the ship backwards. When, for instance, on commencing a new job there is too much water for the spudpoles of a cutter suction dredger or there is too much swell, a so-called "Xmas tree" is used, i.e. a cross of three cables (2 forward and 1 backward) which replaces the spuds.

Trailers do not encounter these problems because they owe their reaction forces to the thrust of the propellers. For oil exploration an exploratory vessel is kept in place by 4 electronically-controlled Voith-Schneider propellers. Generally anchorage problems are very time-consuming and may cause serious production losses.

IV-16 HINDRANCE TO SHIPPING

Especially when dredging for maintenance purposes, shipping traffic will almost always be a problem. Sometimes this is also the case when a capital-work is made.
Every dredger is a hindrance to shipping, but this can be reduced by:

a) keeping the number of dredgers as low as possible, e.g. use of units with an optimal production.

b) limiting anchorage hindrance as much as possible by using as many spud poles as feasible (i.e. barge unloading dredger or grab crane).

c) using a floating device (trailer).
In this respect trailers (fig. V-9.1) have a considerable advantage in harbour basins. However, this does not imply that they will not cause any hindrance at all.
When dredging they can block up the other traffic because of their slow operation speed.
Moreover, during dredging they are less manoeuvrable than ordinary ships.
And when turning, of course, they transverse the normal sailing course.

IV-17 DANGER OR HINDRANCE TO THE ENVIRONMENT

Danger

IV-17.1 Subsidence of existing works as a result of undermining.

IV-17.2 By subsoil failure, causing soil disturbances in neighbouring areas.

IV-17.3 Leakage in pipelines along public roads, particularly during sub-zero temperatures when this can be extremely dangerous to motor traffic.

IV-17.4 Anchor wires stretched across a public area may destroy anything nearby if they break, snap or jump.

IV-17.5 Damage to cables and underwater-mains.

IV-17.6 Transport vessels colliding with other boats and/or civil engineering works (fenders etc.)

IV-17.7 When using explosives: vibration and obstruction to road and water traffic, damage to buildings, damage to fish.

IV-17.8 Dredging of explosives.

Hindrance

IV-17.9 Deviation of cut off roads and waterways when, for instance, a dredger is commencing a new job.

IV-17.10 Transport of portable equipment by road.

IV-17.11 Extra passages through moveable bridges and sluices.

IV-17.12 In deeper water, influence on waves and fish stock, due to stratification.

IV-17.13 Increased water seepage, sometimes introducing brackish water.

IV-17.14 Noise, especially from the squeaking of a bucket dredger.

IV-17.15 Temporary passage required over pipelines and fill areas.

IV-17.16 Passage of pipelines over fields and properties.

These points may cause a review of an initial plan which had seemed technically to be ideal from the dredging aspect and sometimes may even require the use of special equipment.

IV-17.17 Sand drifts on fill areas.

IV-17.18 Smell caused by burning of vegetation, or the spoil in the fill.

IV-17.19 Blocking part of the canal.

IV-17.20 Sailing of spoil barges.

IV-18 POLLUTION

IV-18.1 Silting-up of private and public waterways due to the return of deluting water. ("dredge-water").

IV-18.2 Leaks from pressure pipelines.

IV-18.3 Sand blown away by the wind from fill areas.

IV-18.4 Roads will become dirty by topsoil needed for covering.

IV-18.5 Floating peat "islands" and tree trunks in cases of dredging work in cut.

IV-18.6 Spillage from "dry" earth moving equipment.

IV-18.7 Spillage from barges in public waterways.

IV-18.8 Silting-up in adjoining areas of dump-pits.

IV-18.9 The water becomes muddy when using a trailer which regularly discharges considerable amounts of overflow-slurry into the water.

IV-18.10 Pollution of the water from barges overflowing while loaded by sandwinning dredgers.

IV-18.11 Pollution of the waterways around a barge unloading dredger.

IV-19 AVAILABILITY OF EQUIPMENT

Design and construction of a non-standard dredger takes 1 to 2.0 years. It is clear that in the case of a tender for a dredging work, calculations will be based on the existing equipment, as the time for special manufacture is lacking whilst it is normally not possible to buy from stock.
Availability of ready-made units from stock for smaller projects improves this situation.

For large projects the special manufacture of equipment is only possible for prolonged contracts.
The entire complexity of the availability of equipment can be the cause of considerable differences of tender-prices and also of variations in the ideal plan of execution.

IV-20 POSSIBILITY AND TIME FOR MOBILIZATION AND DEMOBILIZATION OF THE EQUIPMENT

Particularly when working in a remote location the problem of mobilization and demobilization is very important. The towing of dredging equipment requires a considerable time and the cost and insurance premiums are very high. In cases of smaller jobs this is of particular importance. It may therefore be important to lengthen the required completion time in such a way that it would become possible for a portable, demountable machine which can be mobilized by a seaship to carry out the work.
Time saved on mobilization can be used for production. Often considerable amounts of money can be saved by efficient mobilization and demobilization.

IV-21 METHOD OF QUANTITY SURVEY

Calculation of the quantity of spoil dredged is often a substantial problem.
In principle one can measure the quantity:

IV-21.1 in the cut

IV-21.2 in the fill

IV-21.3 in the means of transport.

IV-21.1 When measuring in the cut area inaccuracies occur because of:

IV-21.1.1 the sounding weight not hanging perpendicular due to current sweep

IV-21.1.2 false echos on drifting slurry when echo-sounding

IV-21.1.3 sand movement and siltation

IV-21.1.4 scouring by the current.

IV-21.2 When measuring in the fill there might be inaccuracies because of:

IV-21.2.1 sinking, slides and shrinkage of the sub-soil

IV-21.2.2 transport of fine sand through the water discharge gates

IV-21.2.3 loss of sand by wind erosion

IV-21.2.4 washing away of sand or gravel when dumping in flowing water

IV-21.2.5 loss by wave-wash and currents

IV-21.2.6 the accuracy of measuring as such

IV-21.3 When measuring in the means of transport for determining the quantity handled, the following points are important:

IV-21.3.1 the accuracy of the measurement

IV-21.3.2 the bulking (or swelling)

In many cases measuring in the means of transport is preferred because it is the most reliable calculation of the work done by the contractor.
However, in practice this can only be done with sufficient accuracy in a transport vessel or, for instance, in a lorry.
Up to now, measuring in a pipeline has not proved to be sufficiently accurate, though experimental set-ups have been tested.
Sometimes barges are used in the process to make the measurement possible. The method of measuring defines the method of execution of the work and the equipment required in this case.

V DESCRIPTION AND SKETCHES OF THE MAIN DREDGING AND AUXILIARY EQUIPMENT OF TODAY

LIST OF FIGURES

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V-5.5 Method of advancing along the cut using a spud carriage

V-5.6 Method of advancing along the cut, anchor positioning

V-6 SUCTION DREDGER

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V-6.1.2 Suction dredger with barge-loading facilities
General lay-out: side elevation - plan

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General lay-out: side elevation - plan - front elevation

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in the vertical plane

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Front elevation with A-frames for the ladder and the hydraulic spuds

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Plan
Front elevation with cut

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AUXILIARY EQUIPMENT

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V-18. 1 Side elevation - plan - front elevation

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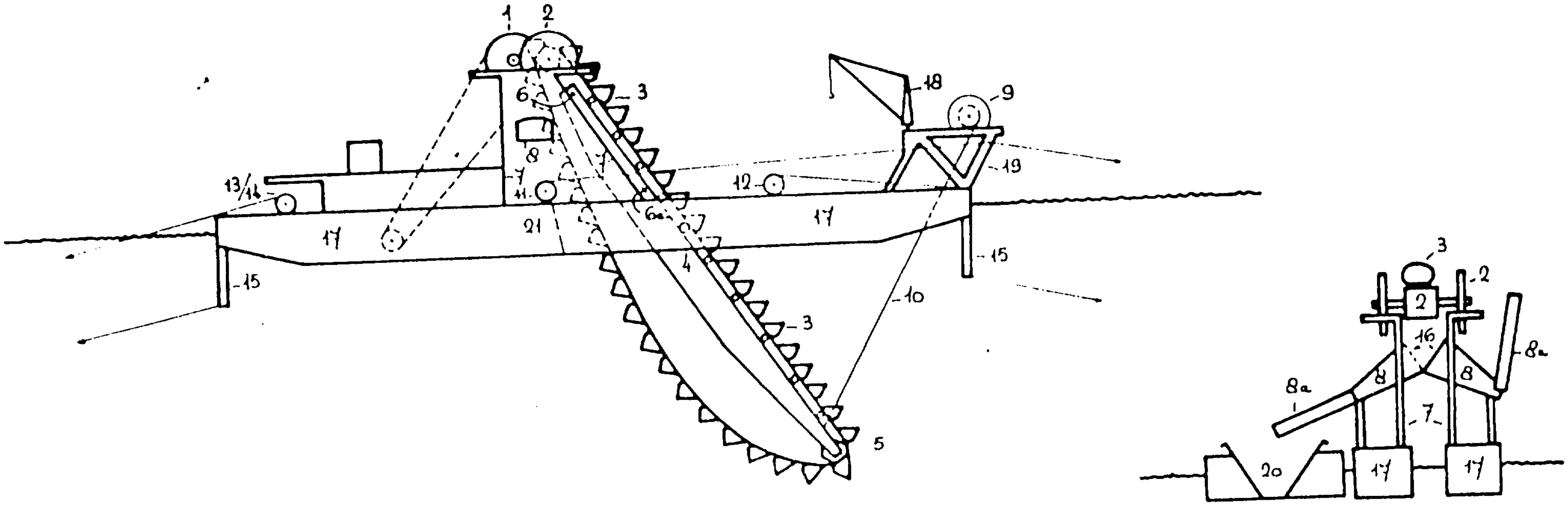
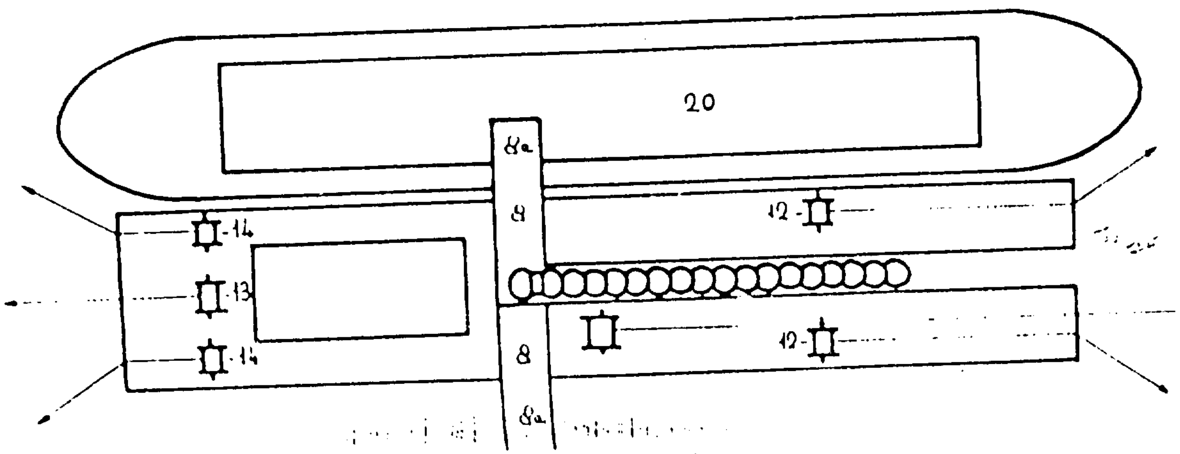
V-19. 1 General lay-out, side elevation, front elevation

FIG. V.1.1.





BUCKET DREDGER

general layout

V-1 BUCKETDREDGER

fig. V-1. 1 General lay-out - elevations - cross section

1. Main driving wheel with pinnion
2. Pentagonal top tumbler on shaft with spur gear wheel(s)
3. Bucket chain
4. Ladder
5. Hexagonal bottom tumbler
6. Pivots for ladder suspension on main frame; the highest position is shown

6a. Ladder pivot (lower position)

7. Main frame
8. Fixed part of side shutes

8a, Hinged part of side shutes

9. Ladder hoist winch
10. Ladder hoist wire (purchase wire)
11. Headline winch
12. Forward sideline winches
13. Sternline winch
14. Aft sideline winch
15. Underwater fairleads
16. Change- over door (clapper door)
17. Hulk
18. Bucketing crane
19. Forward gantry
20. Barge
21. Well end

P.S. On main frame:

auxiliary ladder not shown

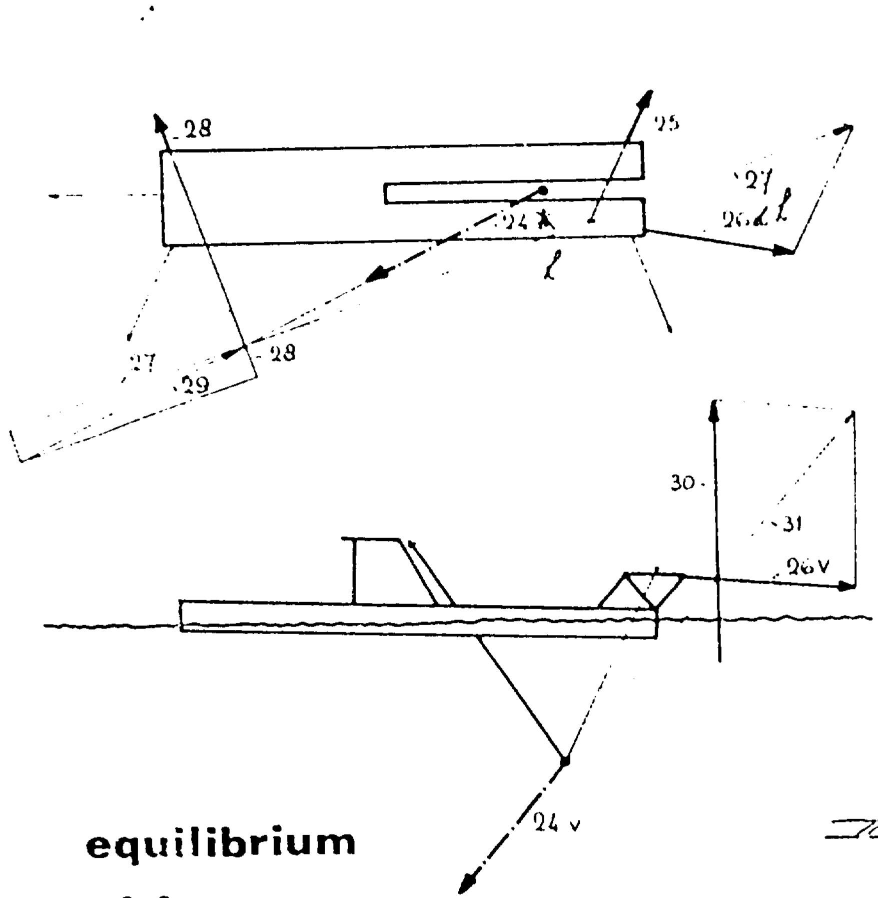
On main deck:

Winches for hinged part of shutes and mooring of barges not shown.

FIG. V-1.1

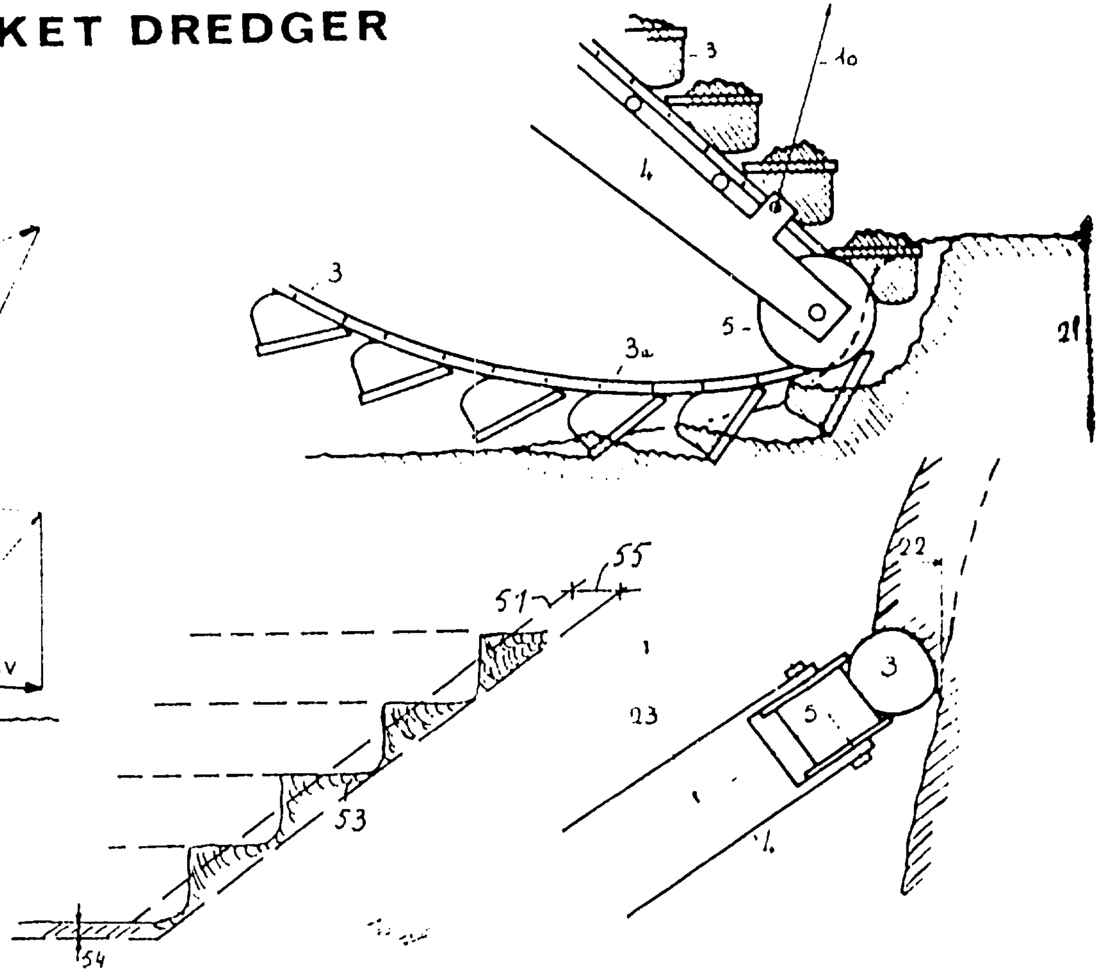
BUCKET DREDGER

FIG. V.1.3.



equilibrium of forces

FIG. V.1.2.



excavation technique

V-1 BUCKETDREDGER

fig. V-1.3 Equilibrium of forces

a. in the horizontal plane

24-h Resultant of curring and digging forces in horizontal plane

25 Pulling force in port forward side wire

26-h Pulling force in head wire (resultant in horizontal plane)

27 Resultant of 25 and 26h

28 Pulling force of port aft side wire

29 Resultant of all anchoring forces

b. in the vertical plane

24-v Resultant of cutting and digging forces in the vertical plane

30 Resultant of buoyancy forces and weight of the vessel

26-v Resultant of head wire and side wire forces in the vertical plane

31 Resultant wire forces, own weight and buoyancy forces in the vertical plane

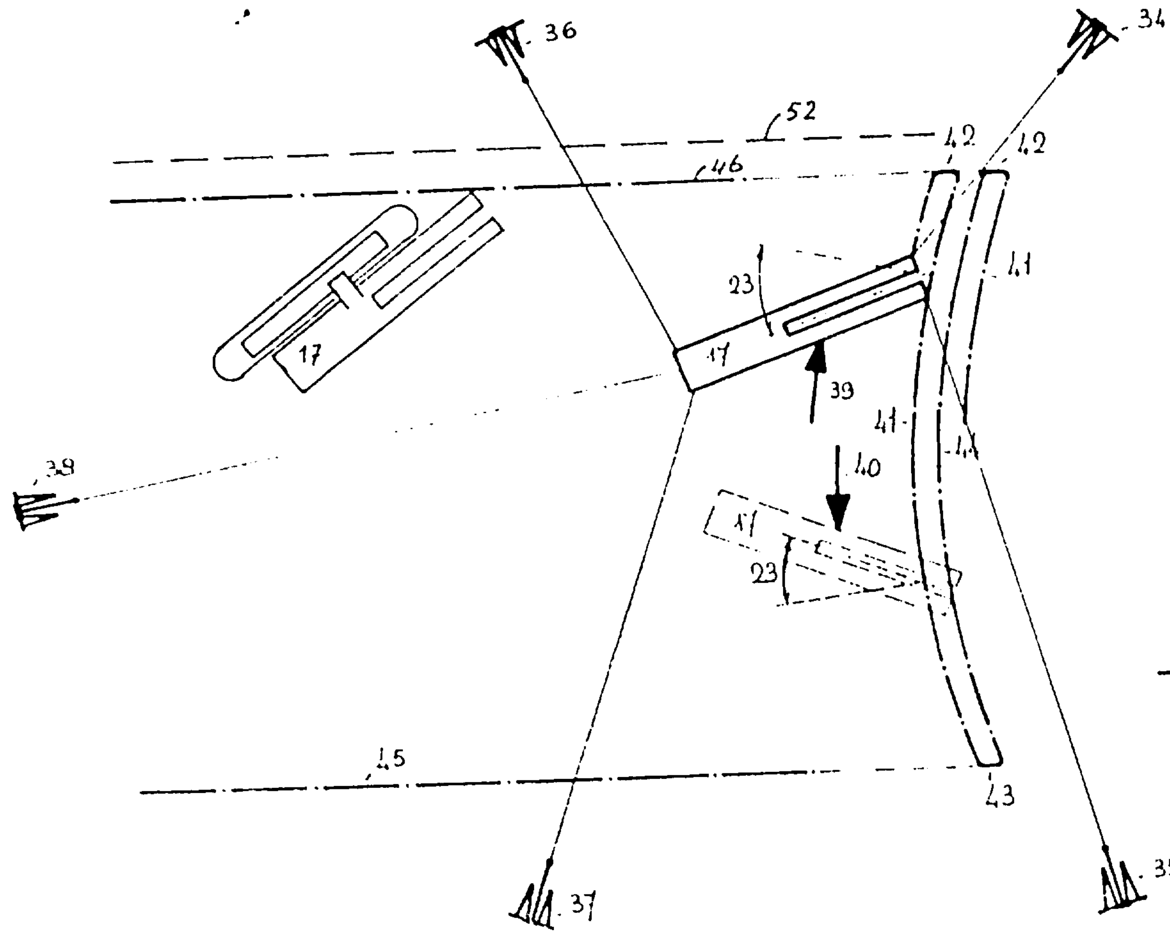
fig. V-1.2 Method of excavation

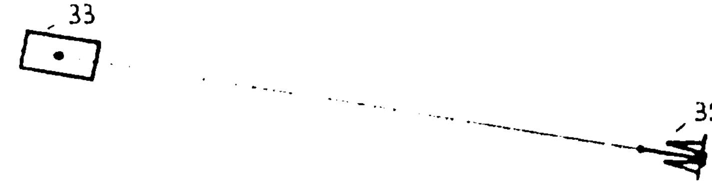
3. Bucket chain
4. Ladder
5. Bottom tumbler (hexagonal)
10. Ladder hoist wire
21. Height of cut
22. Heaving distance (length of a forward step)
23. Angle between centre lines of dredger and axis of the channel (necessary to prevent the bucket chain from slipping off the bottom tumbler)
51. Design slope
53. Box-cut
54. T_v (vertical tolerance)
55. T_h (horizontal tolerance)

FIG. V-1.2
V-1.3

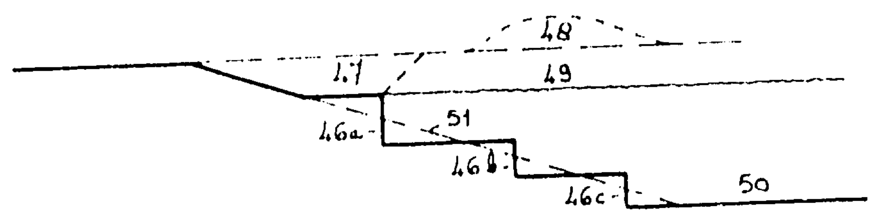
FIG. V.1.4.

BUCKET DREDGER





method of traversing along the cut



cross section

V-1 BUCKET DREDGER

fig. V-1.4 Method of traversing along the cut

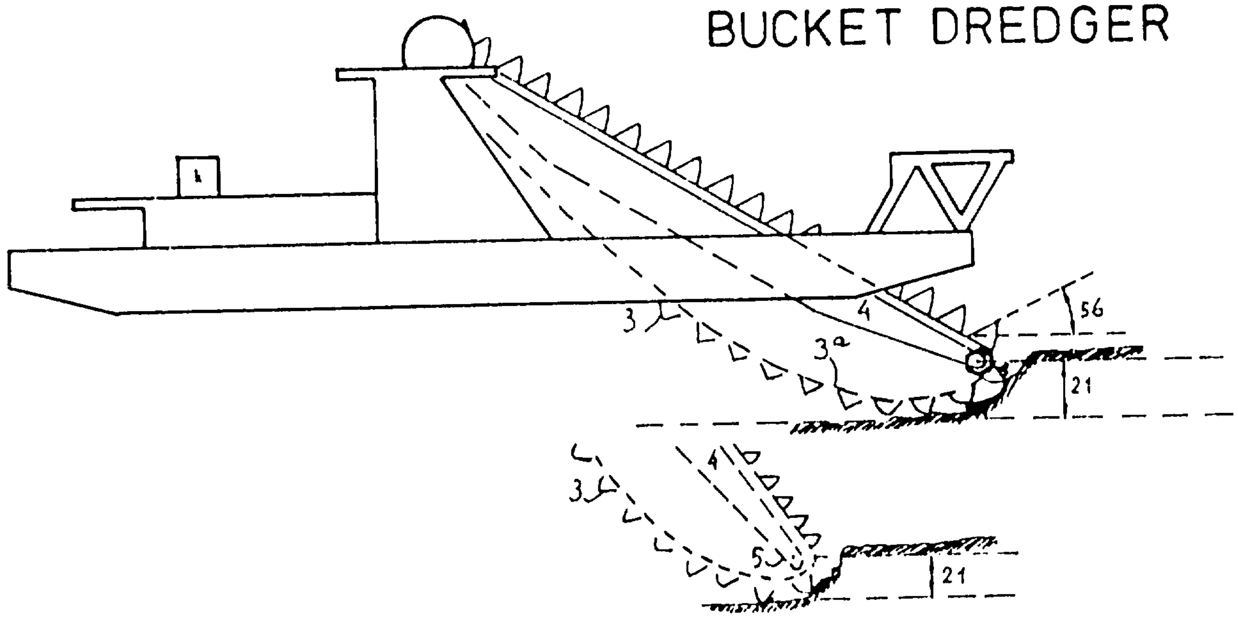
17. Plan of the bucket dredger
32. Head anchor
33. Anchor barge
34. Forward side anchor, port side
35. Forward side anchor, starboard
36. Aft side anchor, port side
37. Aft side anchor, starboard
38. Aft main anchor
39. Swing to port
40. Swing to starboard
41. Path of bottom tumbler during swing to starboard
42. Path of bottom tumbler during heaving of head wire over port side limit of swing
43. Path of bottom tumbler during heaving over starboard
44. Path of bottom tumbler during swing to port side
45. Limit of the cut for the swing to starboard
46. Limit of the cut for the swing to port

Cross section

47. Excavation to water level, by dragline or similar
48. Spoil from 47
49. Water level
50. Designed bottom depth
51. Designed slope
46a to c Port side limits of subsequent dredged cuts ("box cuts")
52. Top of slope to be excavated

FIG. V-1.4

BUCKET DREDGER FIG. V.1.5.



dredging depth

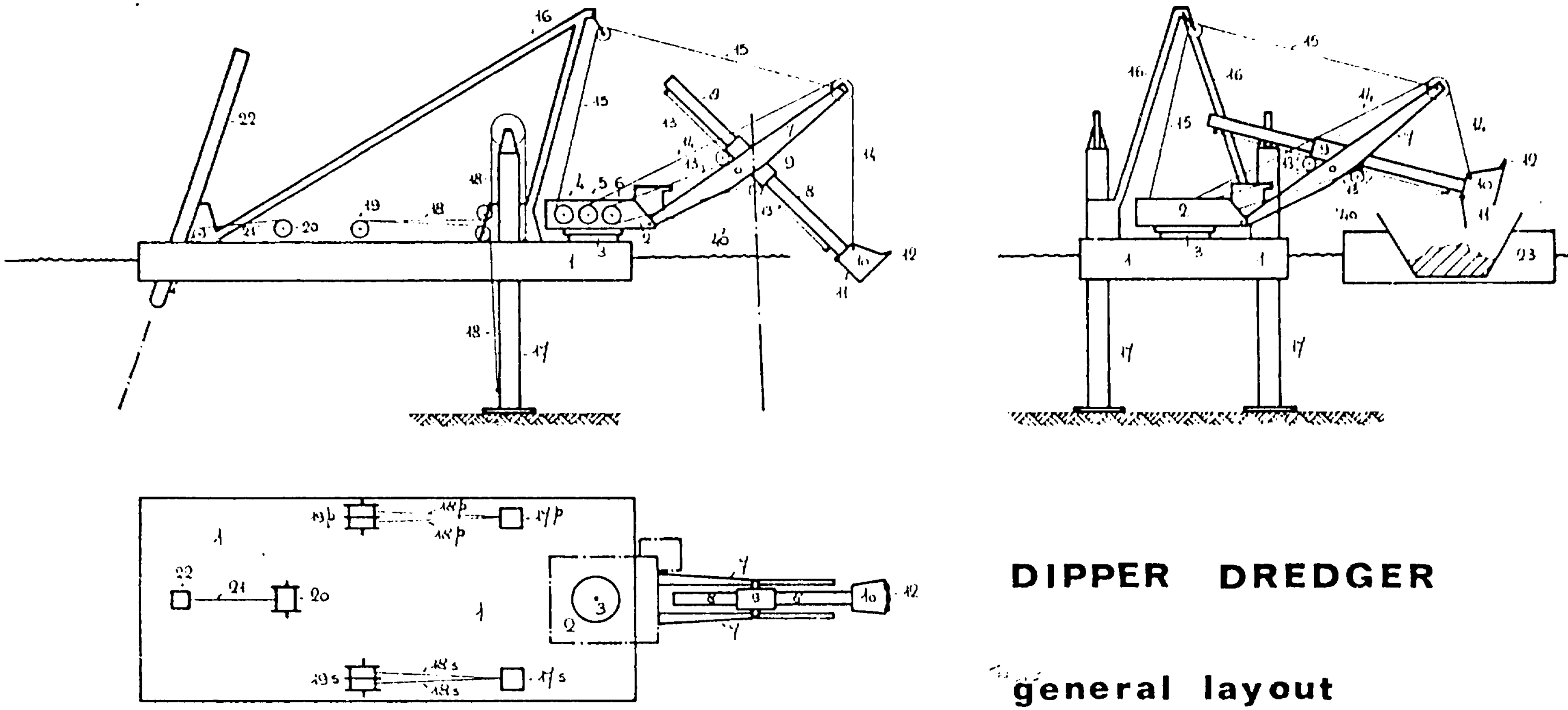
V-1 BUCKET DREDGER

fig. V-1.5 Dredging depth

3. Bucket chain
3a. Sag in the bucket chain
4. Ladder
5. Bottom tumbler (hexagonal)

21. Height of cut
56. Angle to be kept as much near 0^{o} as possible.

FIG. V.2.1.



DIPPER DREDGER

general layout

V-2 DIPPER DREDGER

fig. V-2.1 General lay-out

1. Pontoon
2. Crane cab
3. Slew ring and mounting
4. Luffing drum
5. Digging hoist winch
6. Stick hoist winch
7. Boom
8. Dipper arm
9. Saddle & roller
10. Bucket or dipper
11. Bucket door (hinged bucket bottom)
12. Teeth on bucket
13. Dipper arm wire
14. Bucket wire
15. Boom wire

16. A-frame

(17-s Forward spuds
(17-p

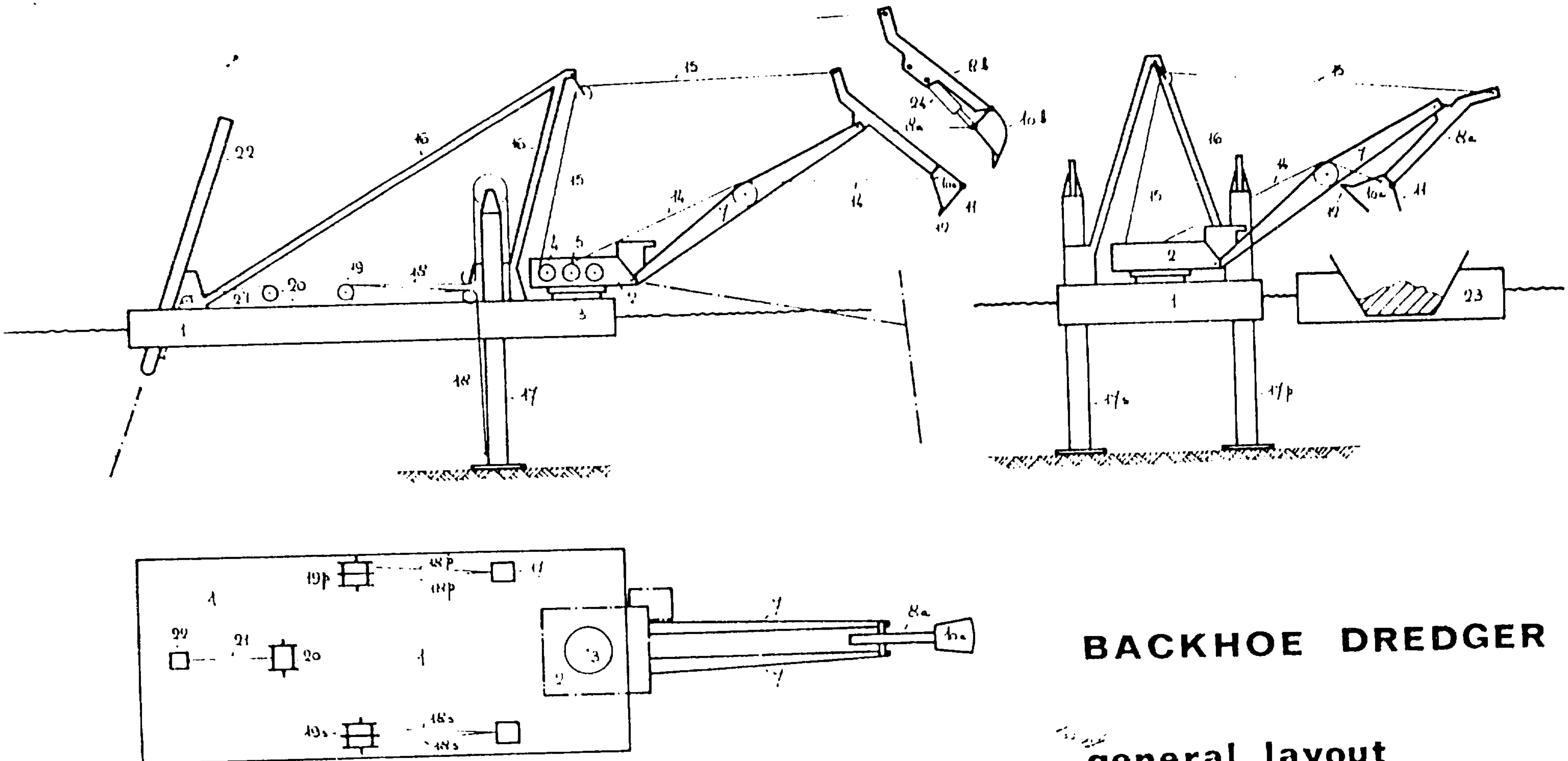
(18-s Spud control wires
(18-p

(19-s Forward spud winches
(19-p

20. Aft spud winch
21. Aft spud wire
22. Trailing spud
23. Barge
40. Backing wire (to pull the bucket backwards)

FIG. V-2.1

FIG. V.2.2.



BACKHOE DREDGER

general layout

V-2 BACKHOE DREDGER

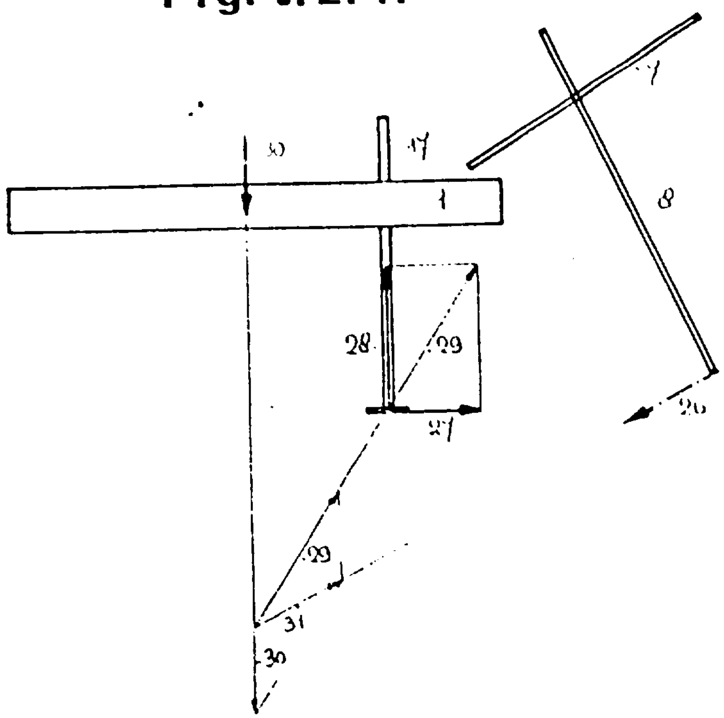
fig. V-2.2 General lay-out

p = Port
s = Starboard

1. Pontoon
2. Crane cab
3. Slew ring and mounting
4. Luffing drum
5. Digging hoist
7. Boom
8a. Bucket arm
8b. Bucket arm for turnable bucket
10a. Dredger bucket
10b. Turnable bucket
11. Bucket door
12. Cutting edge
14. Digging wire
15. Boom wire
16. A-frame
17. Spud
18. Spud control wire
19. Spud winch, with double barrels, two-way drive and clutches and brakes
20. Aft spud winch
21. Aft spud wire
22. Trailing spud
23. Barge
24. Hydraulic ram for manipulating the bucket

FIG. V-2.2

Fig. V. 2.4.



equilibrium of forces

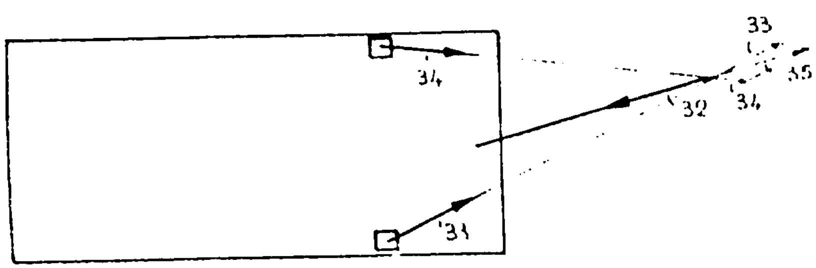
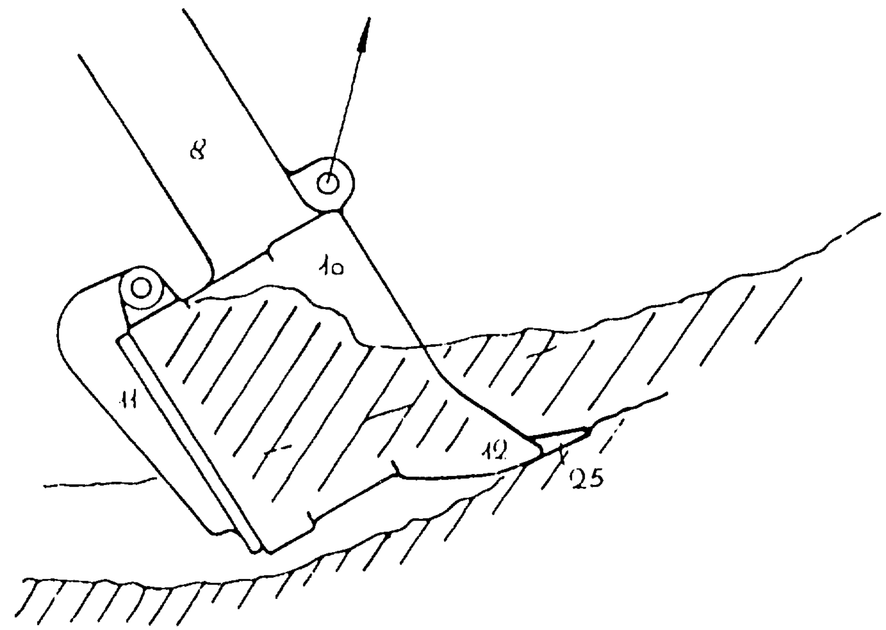


Fig. V. 2. 3.



method of excavation

DIPPER DREDGER

V-2 DIPPER DREDGER

fig. V-2.4 Equilibrium of forces

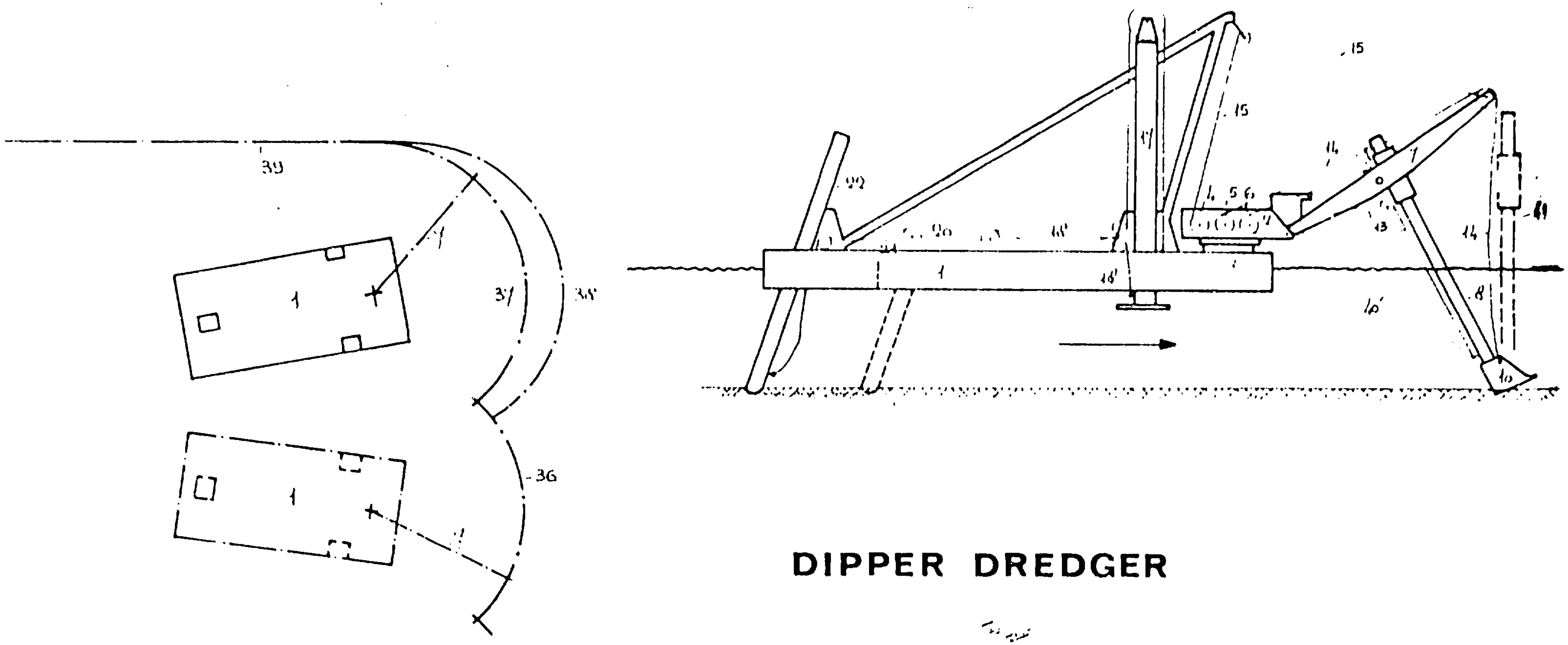
1. Pontoon
7. Boom
8. Dipper arm
26. Resultant of digging and cutting forces in the vertical plane
27. Horizontal bottom-reaction force
28. Vertical bottom-reaction force
29. Resultant of 27 and 28
30. Resultant of weight of vessel and buoyancy forces
31. Resultant of reaction forces in the vertical plane
32. Resultant of digging and cutting forces in the horizontal plane
33. Horizontal reaction force in starboard spudpole
34. Horizontal reaction force in port side spudpole
35. Resultant of reaction forces in the horizontal plane

fig. V.2.3 Method of excavation

8. Dipper arm
10. Bucket or dipper
11. Bucket door
12. Cutting edge of bucket
25. Tooth on bucket

FIG. V-2.3
V-2.4

FIG. V.2.5.



DIPPER DREDGER

method of progressing along the cut

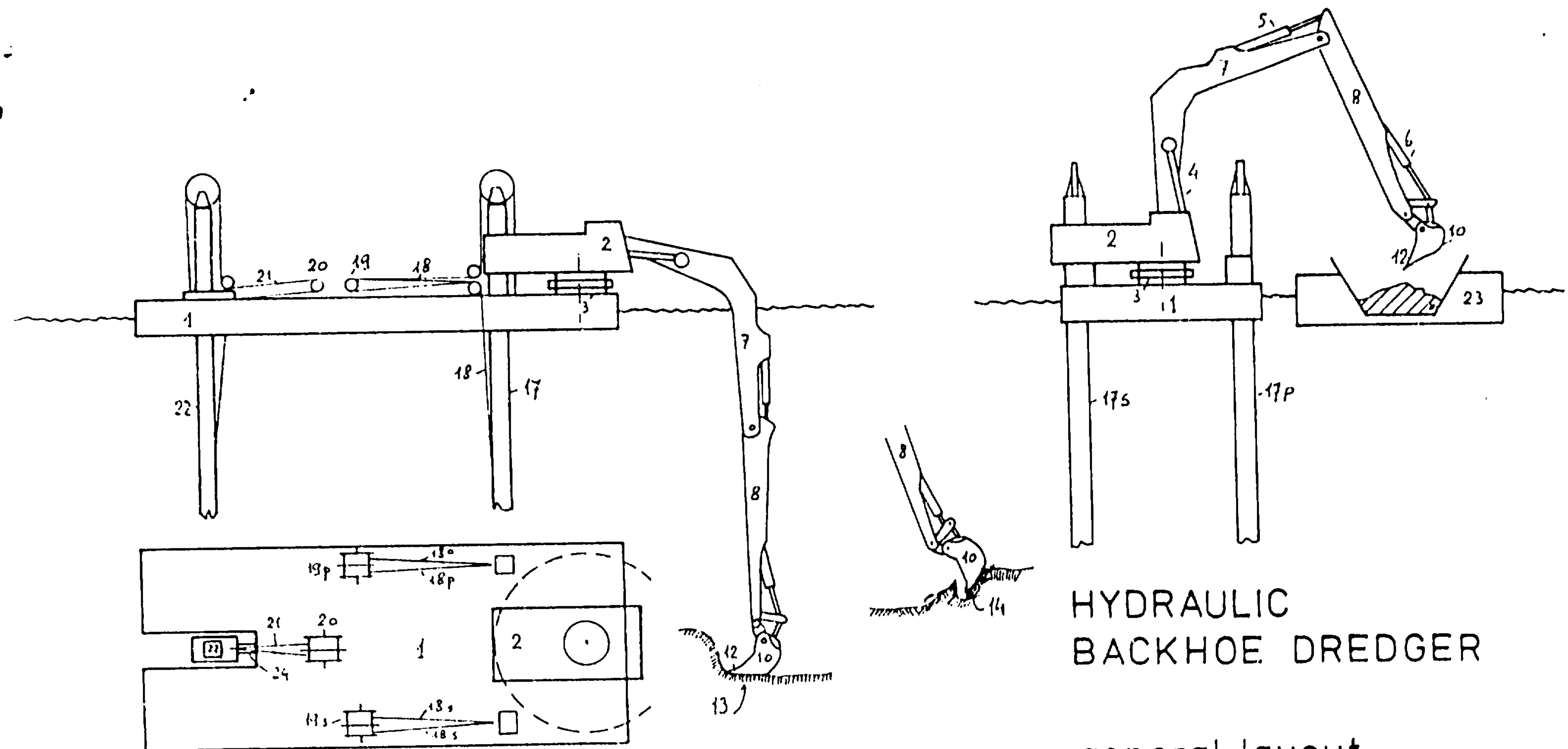
V-2 DIPPER DREDGER

fig. V-2.5 Method of progressing along the cut

1. Pontoon
2. Crane cab
3. Slew ring and mounting
4. Luffing drum
5. Digging hoist winch
6. Stick hoist winch
7. Boom
8. Dipper arm
10. Bucket
13. Dipper arm wire
14. Bucket wire
15. Luffing wire
17. Spud pole in 'up' position
18. Spud control wire
20. Trailing-spud winch
21. Trailing spud wire
22. Trailing-spud
36. Reach of the bucket
37. As 36
38. As 36 after a forward step
39. Side limit of the cut
40. Backing wire. With this wire the pontoon is pulled forward while the bucket / bottom is resting on (in) the bottom
41. Position of the dipper-arm after the forward manoeuvre

FIG. V-2.5

FIG. V.2.6.



HYDRAULIC
BACKHOE DREDGER

general layout

V-2 HYDRAULIC BACKHOE DREDGER

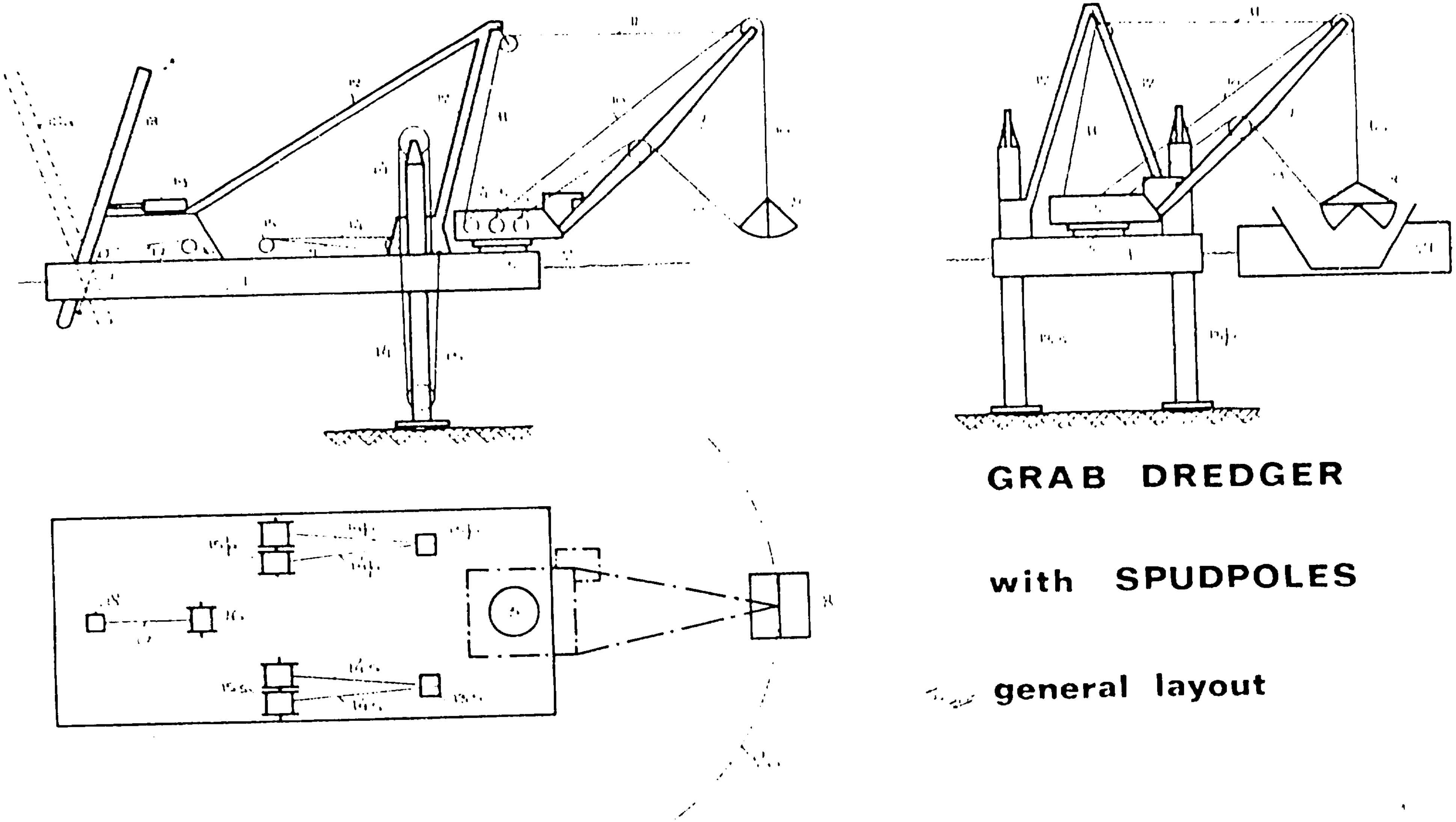
fig. V-2.6 General layout

p = Port
s = Starboard

1. Pontoon
2. Crane cab
3. Slew ring and mounting
4. Boom hydraulic ram
5. Bucket-arm hydraulic ram
6. Bucket hydraulic ram
7. Boom
8. Bucket arm
10. Dredger bucket
12. Cutting edge with teeth
13. Bucket working upwards (undercutting)
14. Bucket working downwards (overcutting)
17. Spud
18. Spud control wire
19. Spud winch with double barrels, two-way drive and clutches and brakes
20. Aft spud winch
21. Aft spud wire
22. Aft spud
23. Barge
24. Hydraulic ram for manipulating the spud-carrier with aft spud.

FIG; V-2.6

FIG. V.3.1.



GRAB DREDGER

with SPUDPOLES

general layout

V-3 FLOATING GRAB

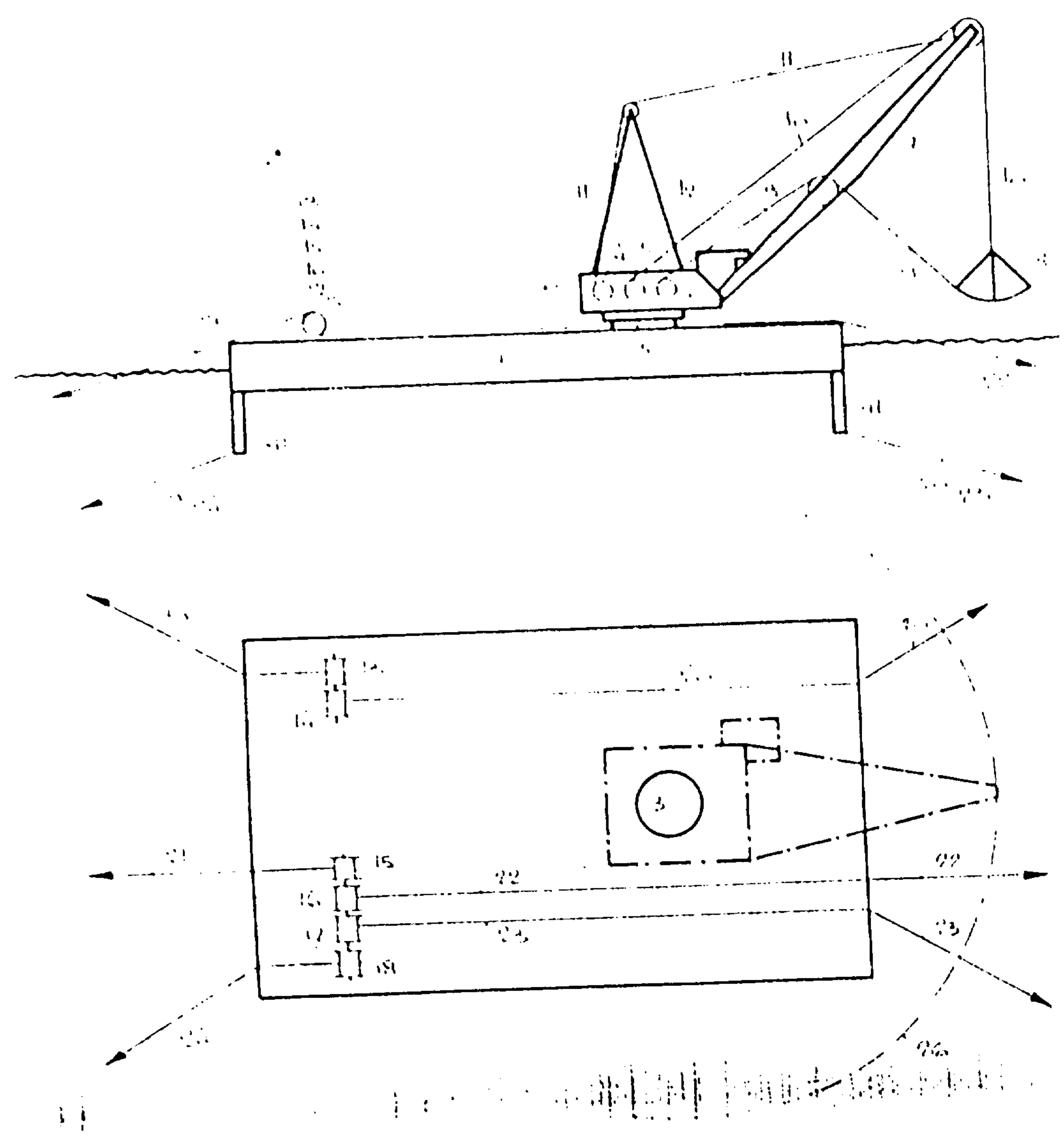
fig. V-3.1 Grab dredger with spudpoles
General plan and elevations

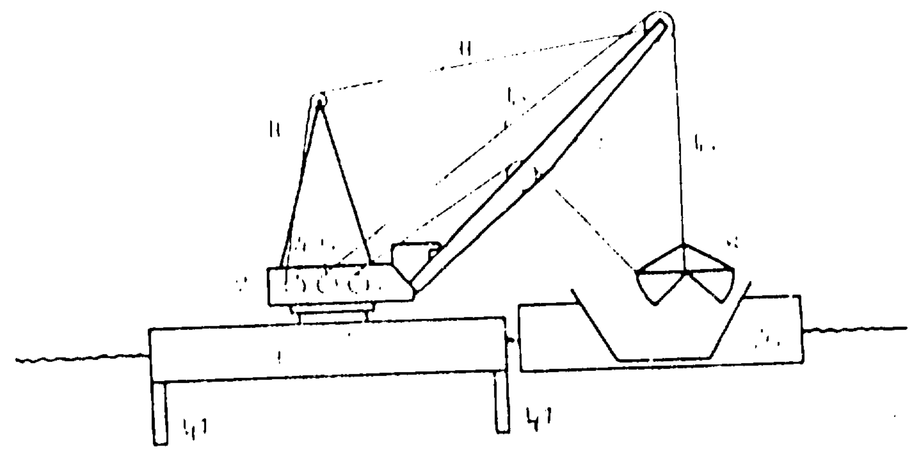
1. Pontoon
2. Crane cab
3. Slew ring and mounting
4. Luffing drum
5. Hoist and hold drums
6. Tagline drum
7. Crane boom (jib)
8. Grab (clamshell)
9. Tagline
10. Hoist and hold wire
11. Luffing wire
12. 'A'-frame
13. Forward spuds
14. Spud control wires
15. Forward spud winches
16. Walking spud winch
17. Walking spud wire
18.18a Walking spud
19. Hydraulic ram for walking spud
20. Range of grab in the horizontal plane
21. Barge

p = port
s = starboard

FIG. V-3.1

FIG. V.3.2.





GRAB DREDGER

at MOORINGS

general layout

V-3 FLOATING GRAB

V-3.2 Grab dredger at moorings

Plan and elevation

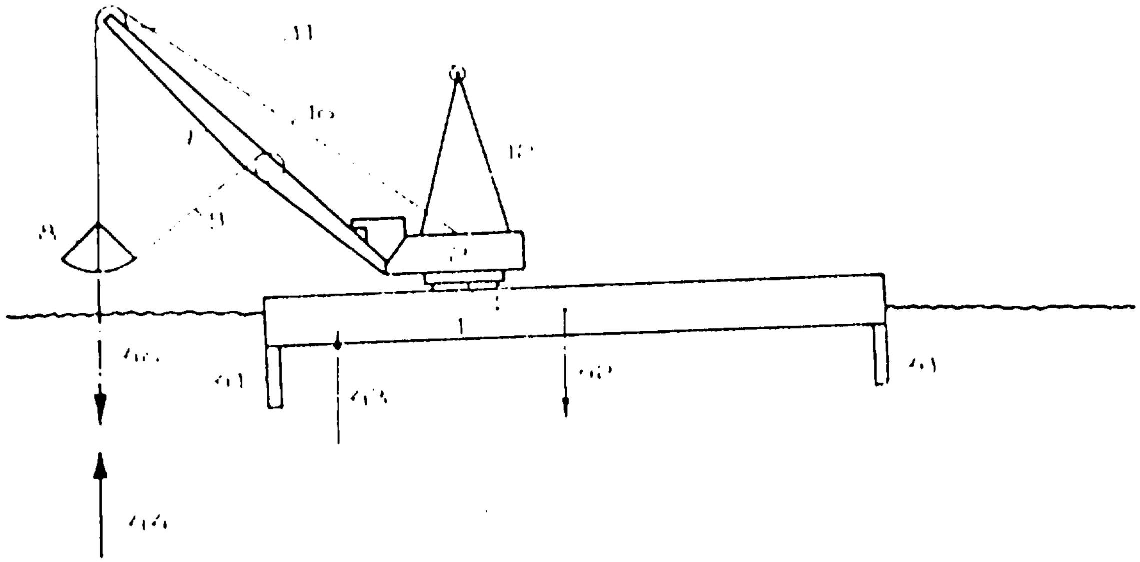
1. Pontoon
2. Crane cab
3. Slew ring and mounting
4. Luffing drum
5. Hoist and hold drums
6. Tagline drum
7. Boom
8. Grab (clamshell)
9. Tagline
10. Hoist and hold wire
11. Luffing wire
12. 'A'-frame
13. Port aft side winch
14. Port forward side winch
15. Aft main winch
16. Forward main winch
17. Starboard forward side winch
18. Starboard aft side winch
19. Port aft side wire
20. Port forward side wire
21. Aft main wire
22. Head main wire
23. Starboard forward side wire
24. Starboard aft side wire
25. Barge

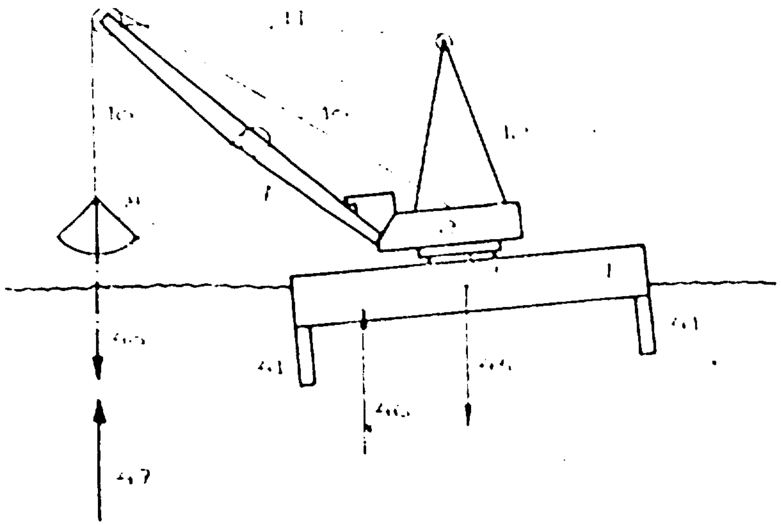
41. Underwater fairleads

26. Range of grab in horizontal plane

FIG. V-3.2

FIG. V. 3. 2.1.





GRAB DREDGER

at MOORINGS

equilibrium of forces
in the vertical plane

V-3 FLOATING GRAB

Grab dredger at moorings

fig. V-3.2.1 Equilibrium of forces in the vertical plane

1. Pontoon
2. Crane cab
3. Slew ring and mounting
7. Boom
8. Grab
9. Tagline
10. Hoist and hold wires
11. Luffing wire
12. 'A'-frame
41. Underwater fairledds

Side elevation

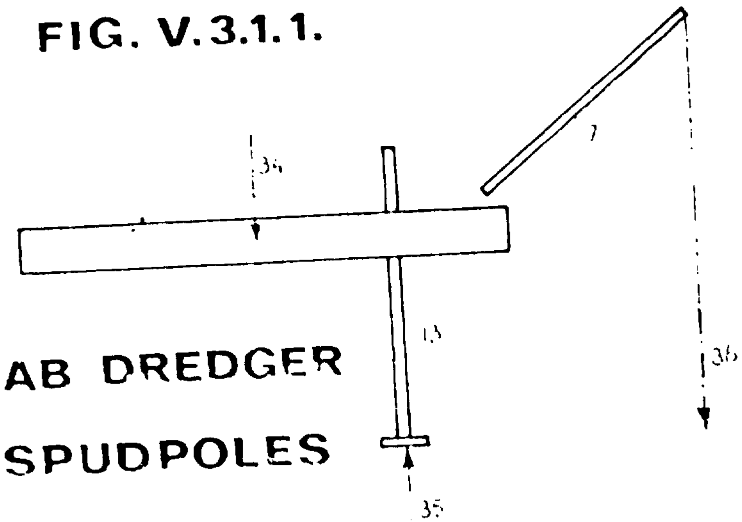
40. Weight of the contents of the grab
42. Resultant of all weights (nr. 40 excepted) (in length direction of the pontoon)
43. Resultant of all buoyancy forces (in length direction of the pontoon)
44. Resultant of 42 and 43

Front elevation

40. Weight of the contents of the grab
45. Resultant of all weights (nr. 40 excepted) (in cross direction of the pontoon)
46. Resultant of all buoyancy forces (in cross direction of the pontoon)
47. Resultant of 45 and 46

FIG. V-3.2.1

FIG. V.3.1.1.



GRAB DREDGER on SPUDPOLES

equilibrium of forces

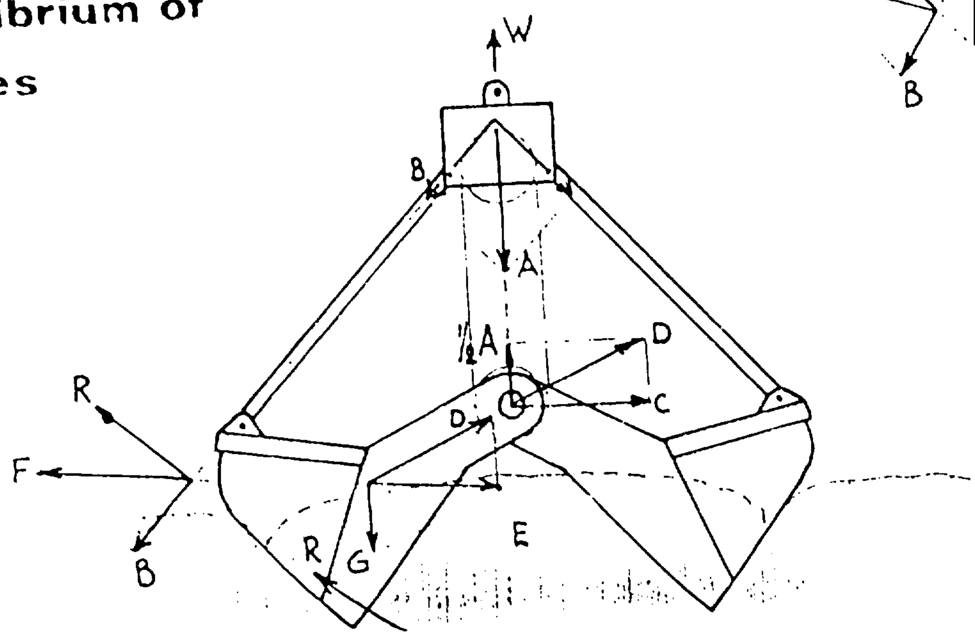
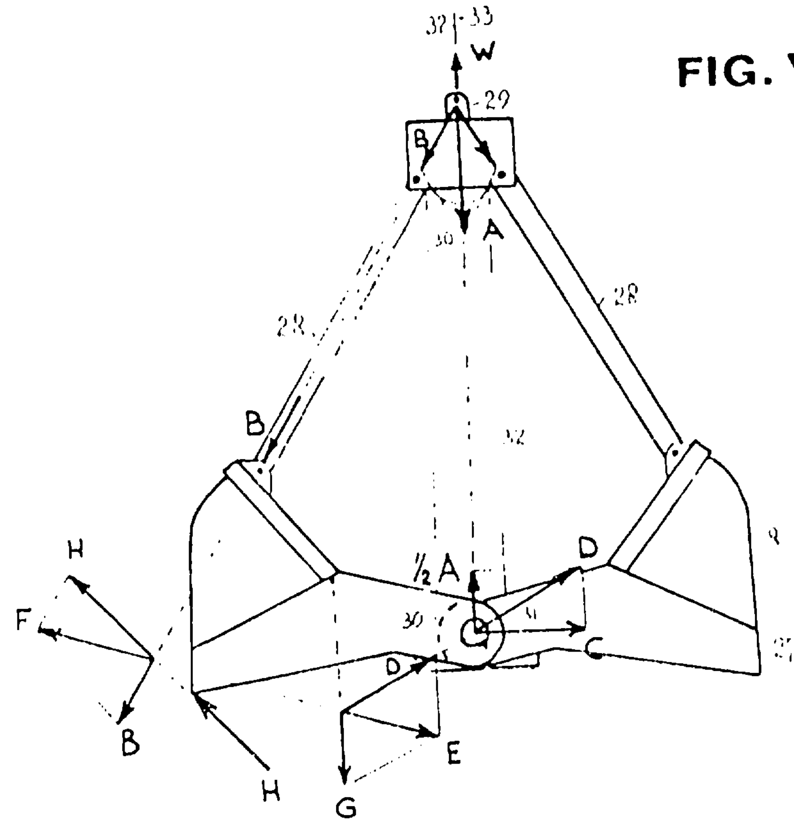


FIG. V.3.3.



GRAB

excavation technique

V-3 FLOATING GRAB

fig. V-3.1.1 Grab dredger on spudpoles

Equilibrium of forces

7. Boom
13. Spudpole
34. Resultant of total weight and buoyancy forces
35. Reaction of bottom on spudpole
36. Weight of filled grab and disengaging forces

fig. V-3.3 Grab

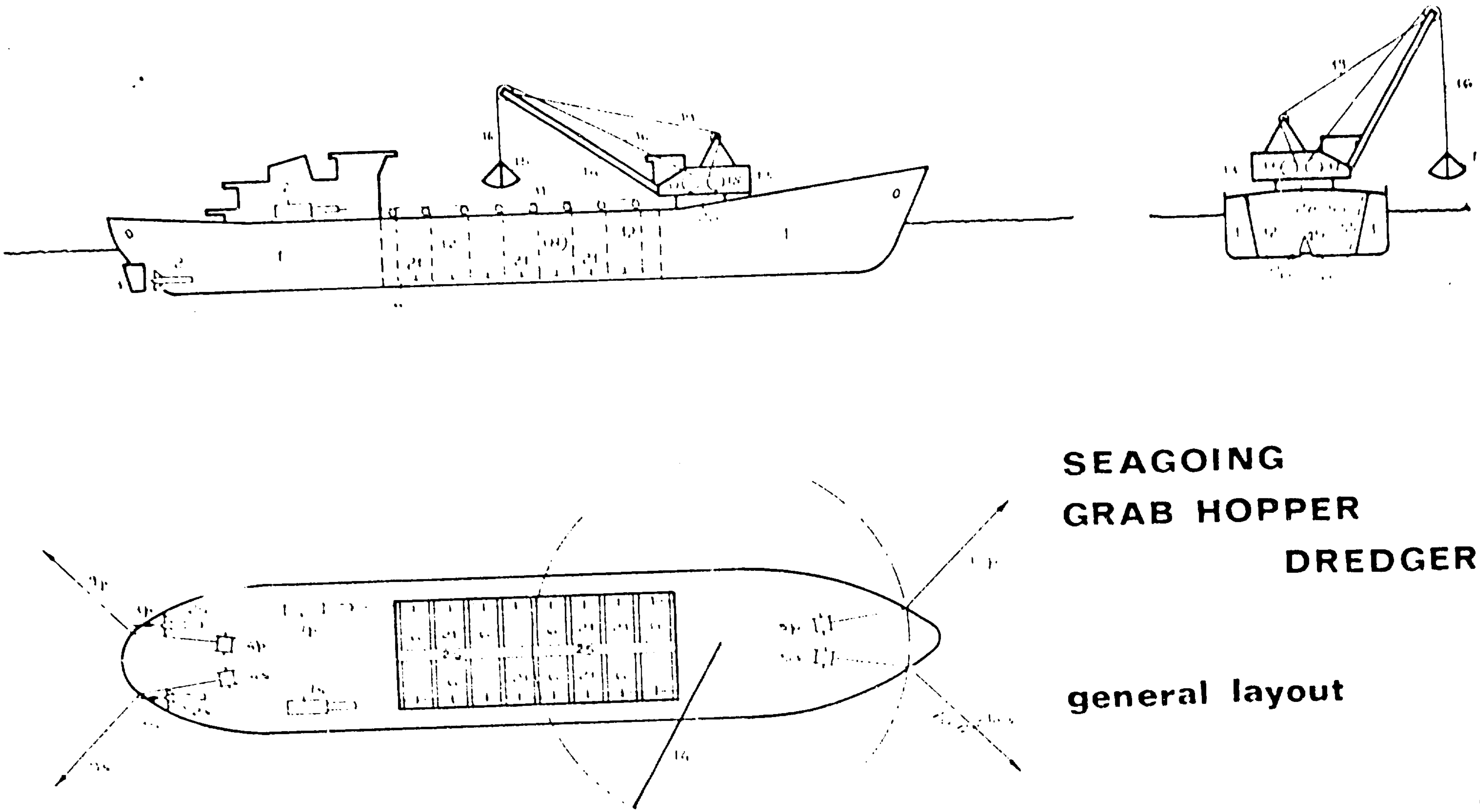
Excavation technique

8. Grab
27. Cutting edges on grab bucket
28. Connecting rod top sheave assembly to grab bucket
29. Lifting eye
30. Sheaves of the closing tackle
31. Hinge of bucket halves
32. Hold wire
33. Hoist wire

Forces:

A - total strain in the closing tackle
B - rods
C - horizontal reaction between bucket halves
D - resultant of ½ A and C
E - resultant of D and G
F - resultant of R and B, equal but opposite to E
G - weight of half grab
H - reaction force of soil on cutting edge
K - total reaction force of soil on half bucket
W - holding wire; force cannot exceed weight of grab plus contents

FIG. V.4.1.



SEAGOING
GRAB HOPPER
DREDGER

general layout

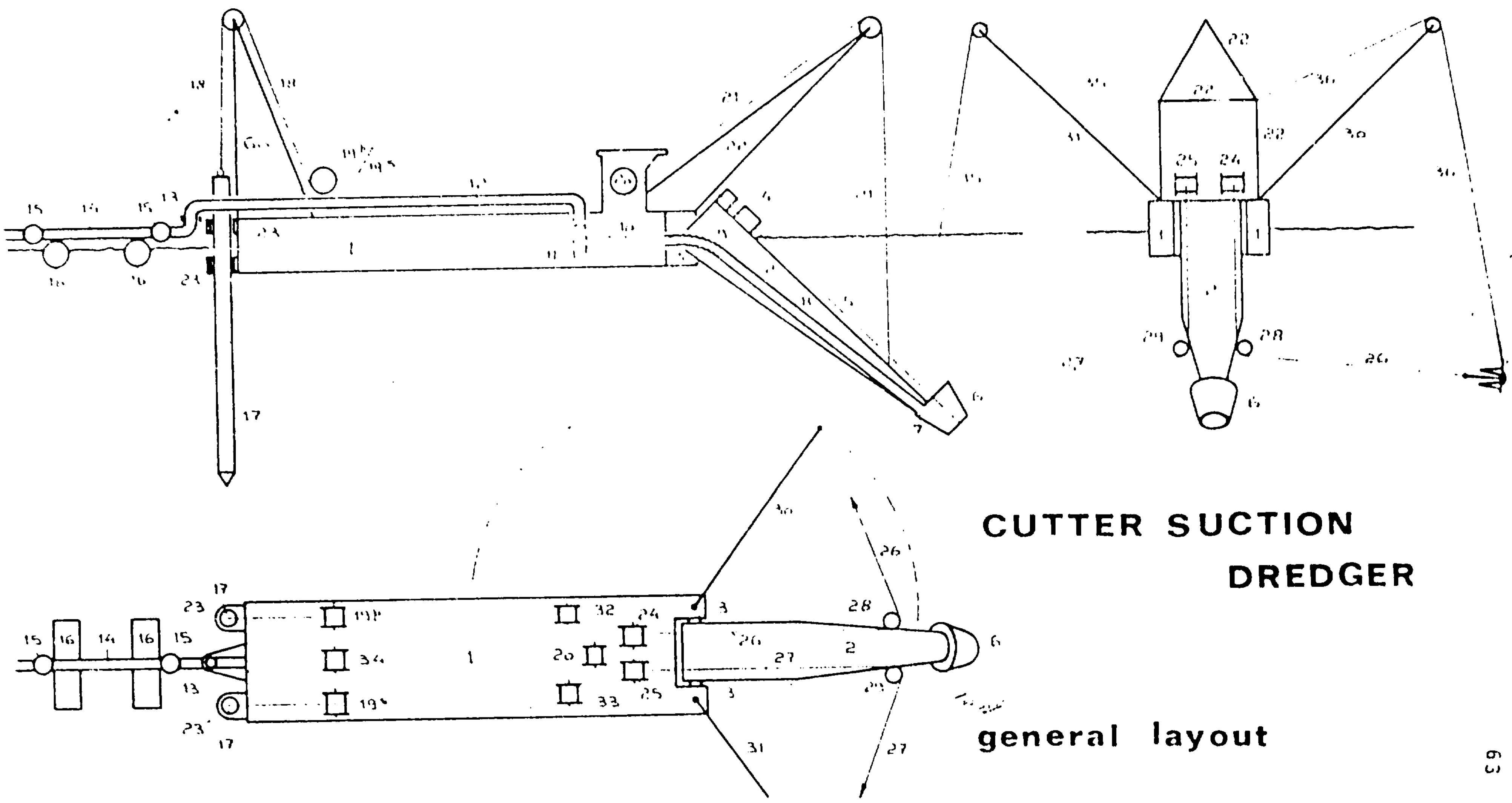
V-4 SEAGOING GRAB HOPPER DREDGER

fig. V-4.1 General lay-out

1. Ship
2. Propeller
3. Rudder
4. Stern side winches
5. Forward side winches
6. Hopper doors
7. Hydraulic rams
8. Hopper
9. Stern side moorings
10. Forward side moorings
11. Door hoisting bars
12. Hopper door chains
13. Crane cab
14. Crane boom (jib)
15. Grab bucket
16. Hoist and hold wire
17. Hoist and hold drum
18. Luffing drum
19. Luffing wire
20. Slew ring and mounting
21. Thwartship Keelson
25. Centre keelson

FIG. V-4.1

FIG. V.5.1.



CUTTER SUCTION DREDGER

general layout

V-5 CUTTER SUCTION DREDGER

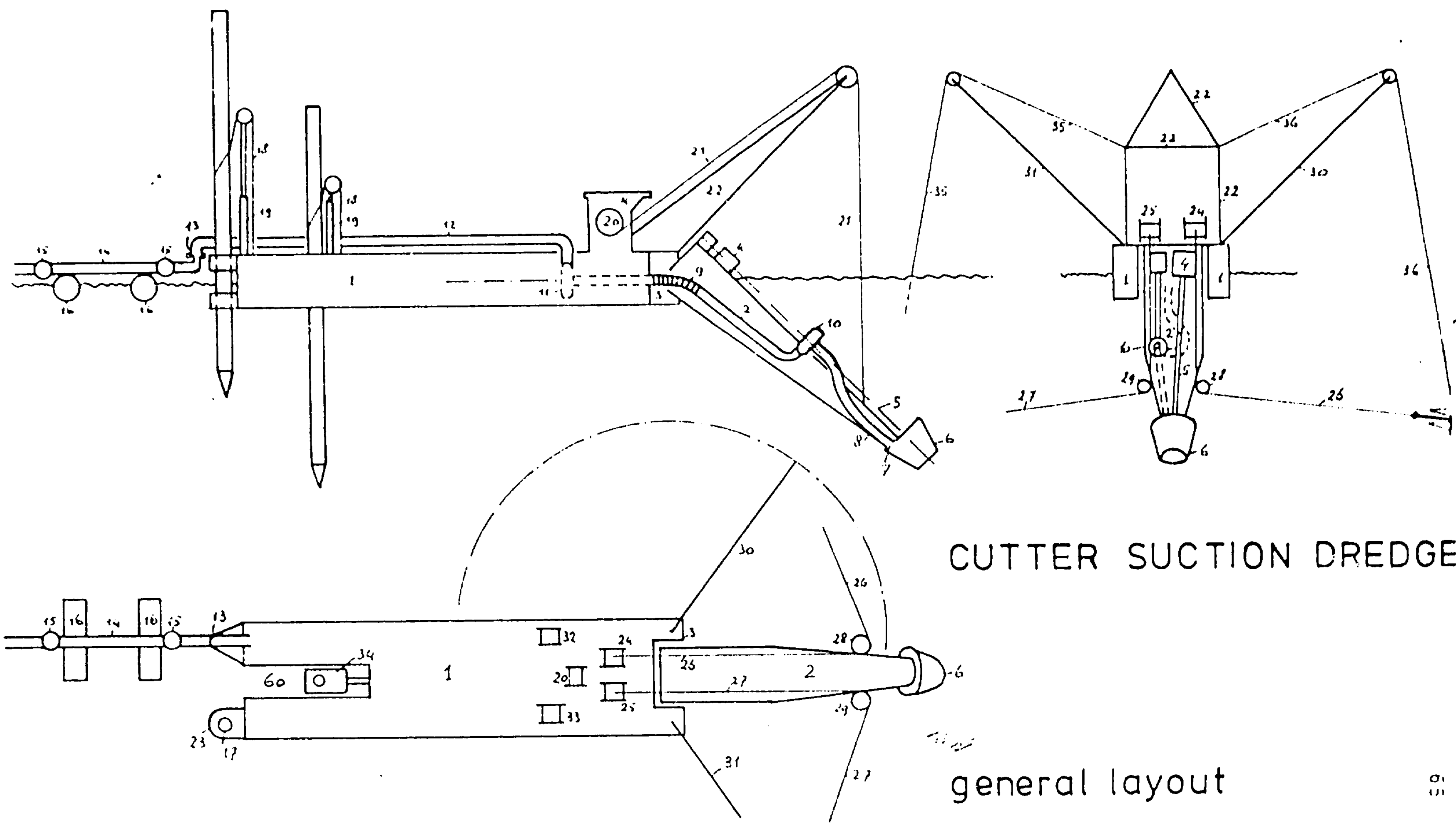
fig. V-5.1 General layout

1. Pontoon
2. Cutter ladder
3. Well with ladder trunnions
4. Cutter motor and gearbox
5. Cutter shaft
6. Cutter
7. Suction mouth
8. Suction tube
9. Reinforced rubber suction hose [suction sleeve (Am.)]
10. Suction pipe in ship
11. Dredge pump
12. Discharge pipe - [discharge outlet (Am.)]
13. Swivel elbow connection [Goose neck (Am.)]
14. Floating pipeline
15. Ball joints
16. Floats
17. Spudpole
18. Spud wire
19. Spudpole hoist
20. Ladder hoist
21. Ladder wire
22. Ladder gantry
23. Spudpole keeper
24. Winch for port side wire
25. Winch for starboard side wire
26. Port side wire
27. Starboard side wire
28. Swingsheave for 26
29. Swingsheave for 27
30. Port anchor boom
31. Starboard anchor boom
32. Port anchor hoist
33. Starboard anchor hoist
34. Stern anchor winch, used for dredging without spuds. (X-mas tree)
35. Port anchor wire
36. Starboard anchor wire
60. Spud gantry

p = port
s = starboard

FIG. V-5.1

FIG. V. 5.1. a.



CUTTER SUCTION DREDGE

general layout

V-5 CUTTER SUCTION DREDGER WITH SPUD CARRIAGE AND SUBMERGED DREDGE PUMP.

fig. V-5.1[a] General lay-out

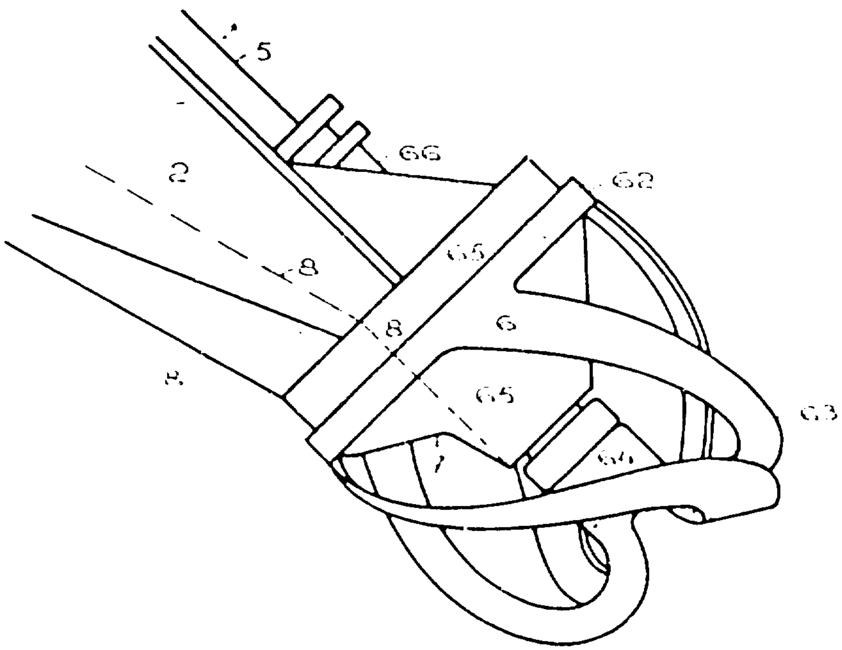
1. Pontoon
2. Cutter ladder
3. Well with ladder trunnions
4. Cutter motor and gearbox
5. Cutter shaft
6. Cutter
7. Suction mouth
8. Suction tube
9. Reinforced rubber suction hose [suction sleeve (Am.)]
10. Submerged dredge pump on ladder
11. Dredge pump
12. Discharge pipe - [discharge outlet (Am.)]
13. Swivel elbow connection [Goose neck (Am.)]
14. Floating pipeline
15. Ball joints
16. Floats
17. Spudpole (step)
18. Spud wire
19. Spudpole hoist ram cylinder
20. Ladder hoist
21. Ladder wire
22. Ladder gantry
23. Spudpole keeper
24. Winch for port side wire
25. Winch for starboard side wire
26. Port side wire
27. Starboard side wire
28. Swingsheave for 26
29. Swingsheave for 27
30. Port anchor boom
31. Starboard anchor boom
32. Port anchor hoist
33. Starboard anchor hoist
34. Spud-carrier and ram cylinder
35. Port anchor pendent wire
36. Starboard anchor pendent wire
60. Spud-carrier well

p = port

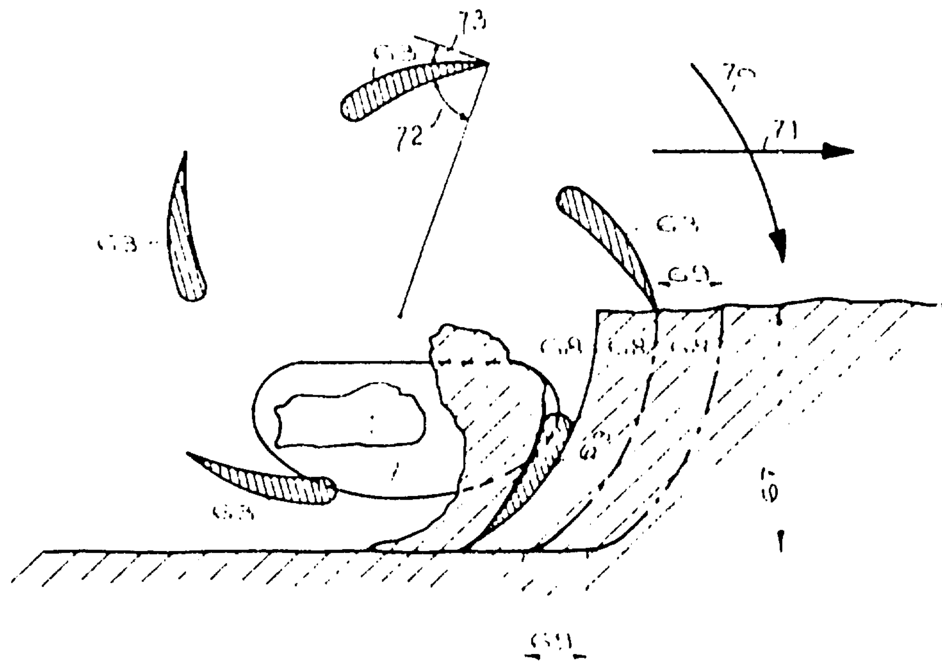
s = starboard

FIG. V-5.1

FIG. V.5.2.1.



cutter turning anti clockwise
working swing to port
in peat and non cohesive material.



CUTTER DREDGER

excavation technique

V-5 CUTTER DREDGER

fig. V-5.2.1 Method of excavation

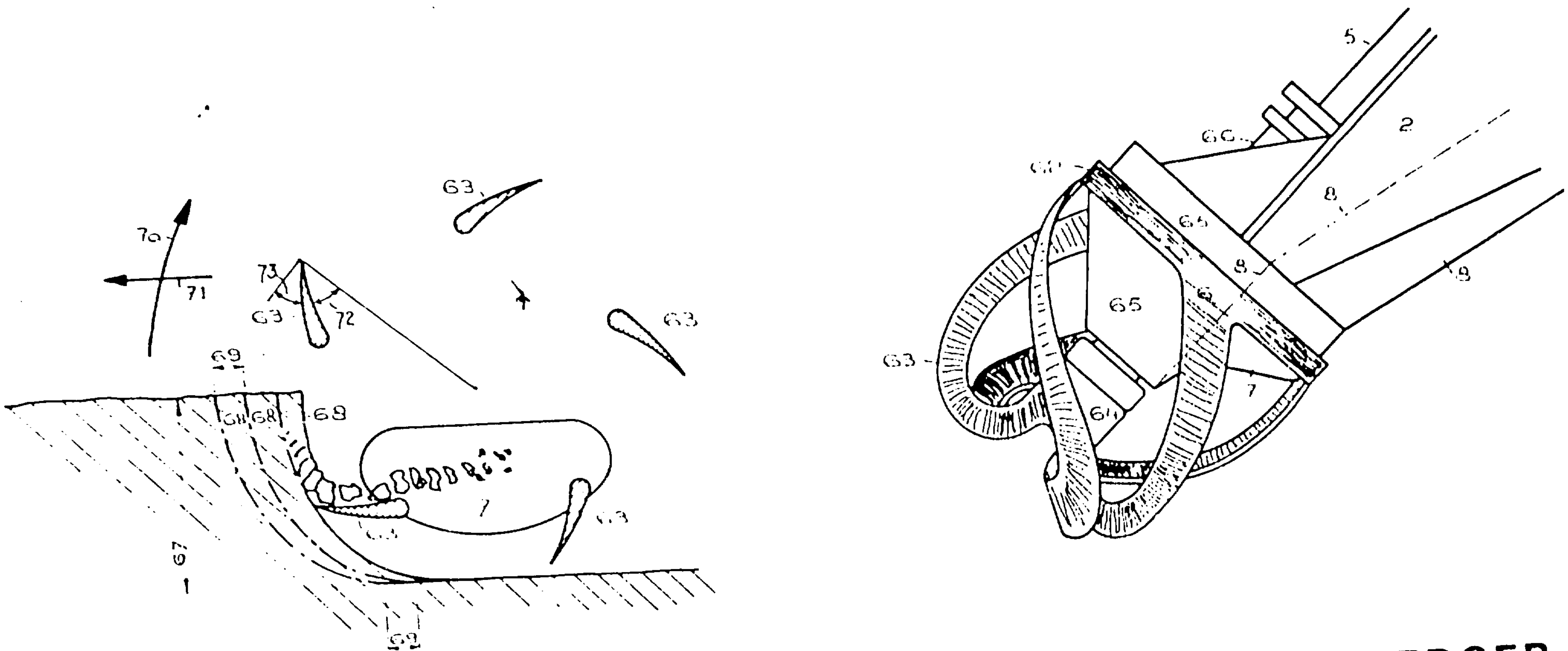
Cutter turning anti clockwise

Working swing to port side, in soft clay, peat and non-cohesive soils

2. Ladder
5. Cutter shaft
6. Cutter
7. Suction pipe orifice
8. Suction pipe
62. Cutter backing ring
63. Cutter blades
64. Hub of the cutter
65. Front of the ladder
66. "Cuttlass" bearing (Rubber end bearing for cutter shaft, lubricated by water)
67. Height of cut
68. Line of cut
69. Width of cut
70. Direction of rotation of cutter
71. Direction of travel of the cutter
72. Angle of rake of cutter blade
73. Clearance angle of cutter blade

FIG. V-5.2.1

FIG. V.5.2.2.



cutter turning anti clockwise (LOOKING FROM WHEELHOUSE !) **CUTTER DREDGER**

swing to starboard

excavation technique

working swing to starboard,

in rock, conglomerates and very hard clay.

V-5 CUTTER DREDGER

fig. V-5.2.2 Method of excavation

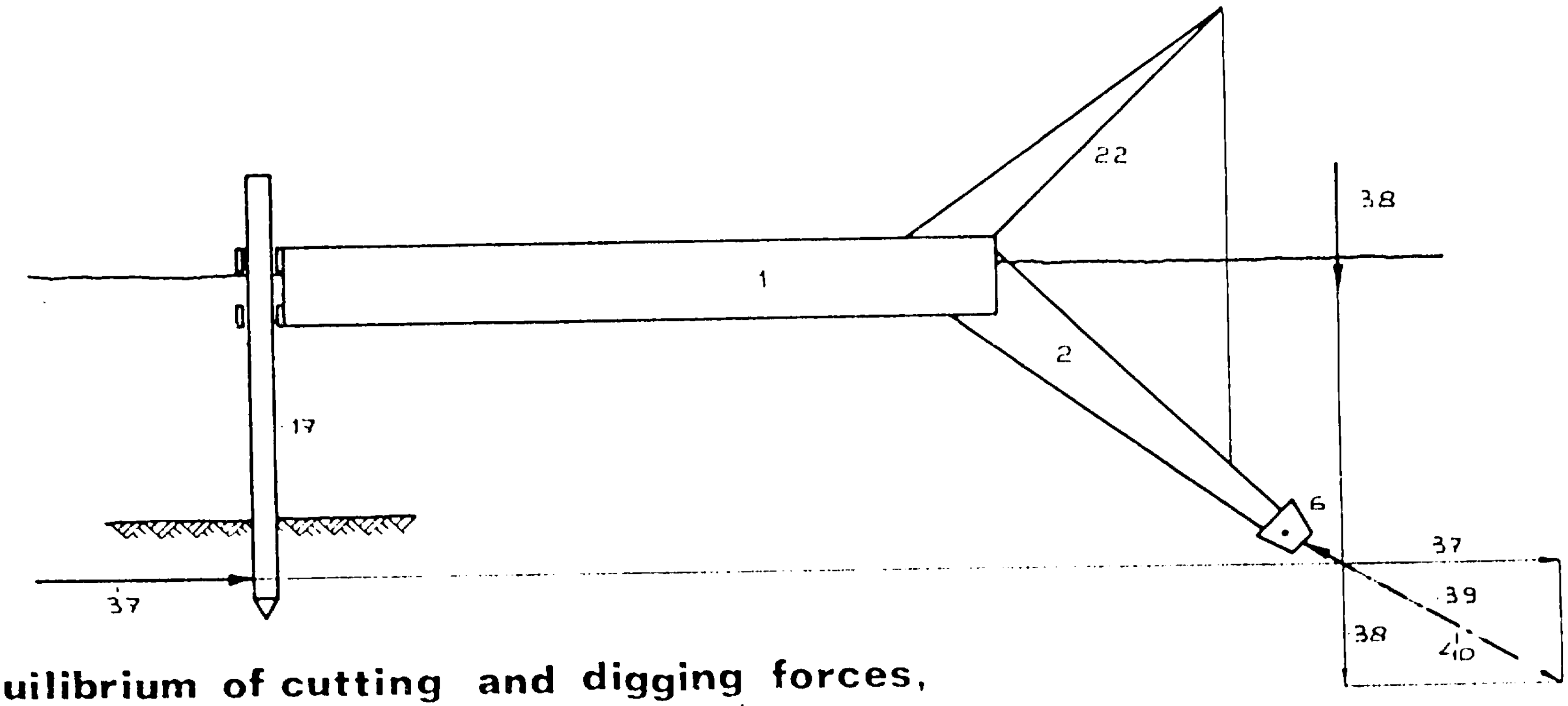
Cutter rotates anti clockwise

Working swing to starboard; in rock, conglomerates and very hard clay

2. Ladder
5. Cutter shaft
6. Cutter
7. Suction pipe orifice
8. Suction pipe
62. Cutter backing ring
63. Cutter blades; fitted with rock points (not shown)
64. Hub of the cutter
65. Front assembly of the ladder
66. "Cuttlass" bearing (Rubber end bearing for cutter shaft, lubricated by water)
67. Height of the cut
68. Line of cut
69. Width of cut
70. Direction of rotation of the cutter
71. Direction of travel of the cutter
72. Angle of rake of the cutter blade
73. Clearance angle of the cutter blade

FIG. V-5.2.2

FIG. V.5.3.1.



equilibrium of cutting and digging forces, with ship- and spud reactions in the vertical plane.
swing to port, cutter turning clockwise.

CUTTER DREDGER

V-5 CUTTER DREDGER

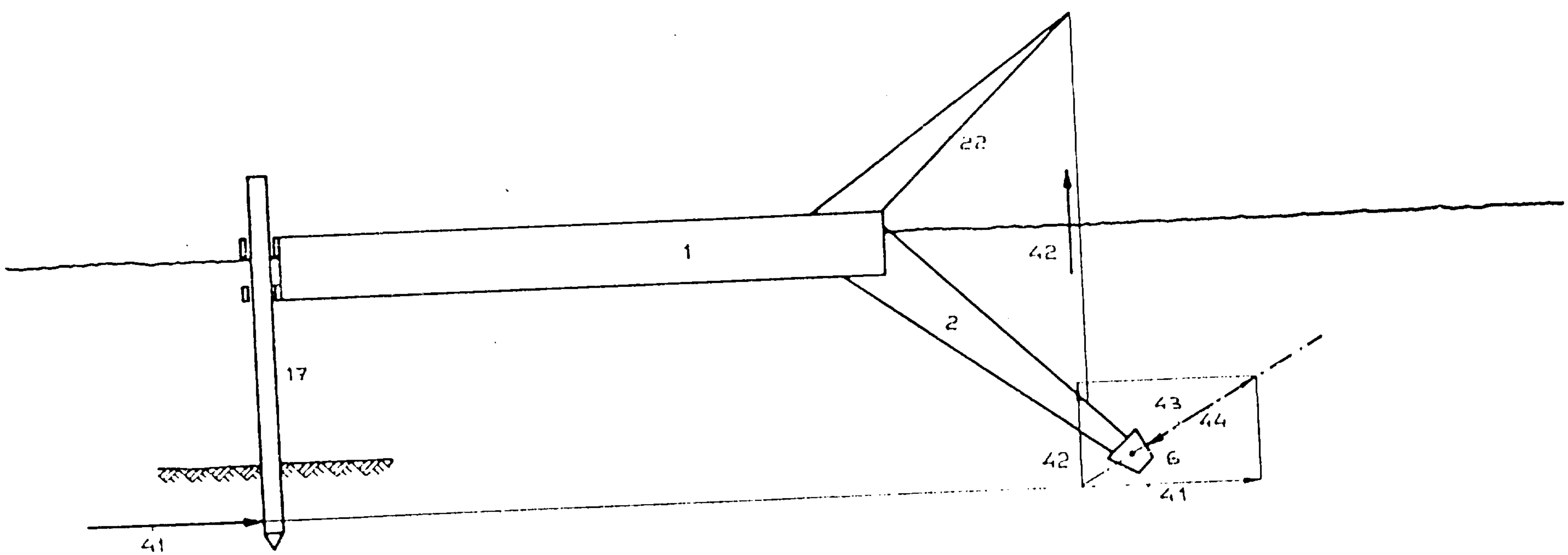
fig. V-5.3.1 Equilibrium of forces in the vertical plane
Swing to port, cutter rotates clockwise

1. Pontoon
2. Ladder
6. Cutter
17. Spudpole
22. Ladder gantry
37. Reaction force on tip of spudpole
38. Resultant of total weight and buoyancy forces
39. Compotent of the soil forces on the cutter in the vertical plane
40. Resultant of 37 and 38

P.S. Of all forces only the compotent in the vertical plane is dealt with.

FIG; V-5.3.1

FIG. V.5.3.2.



equilibrium of cutting and digging forces, with ship- and spud reactions in the vertical plane.

starboard swing, cutter turning clockwise.

CUTTER DREDGER

V-5 CUTTER DREDGER

fig. V-5.3.2 Equilibrium of forces in the vertical plane

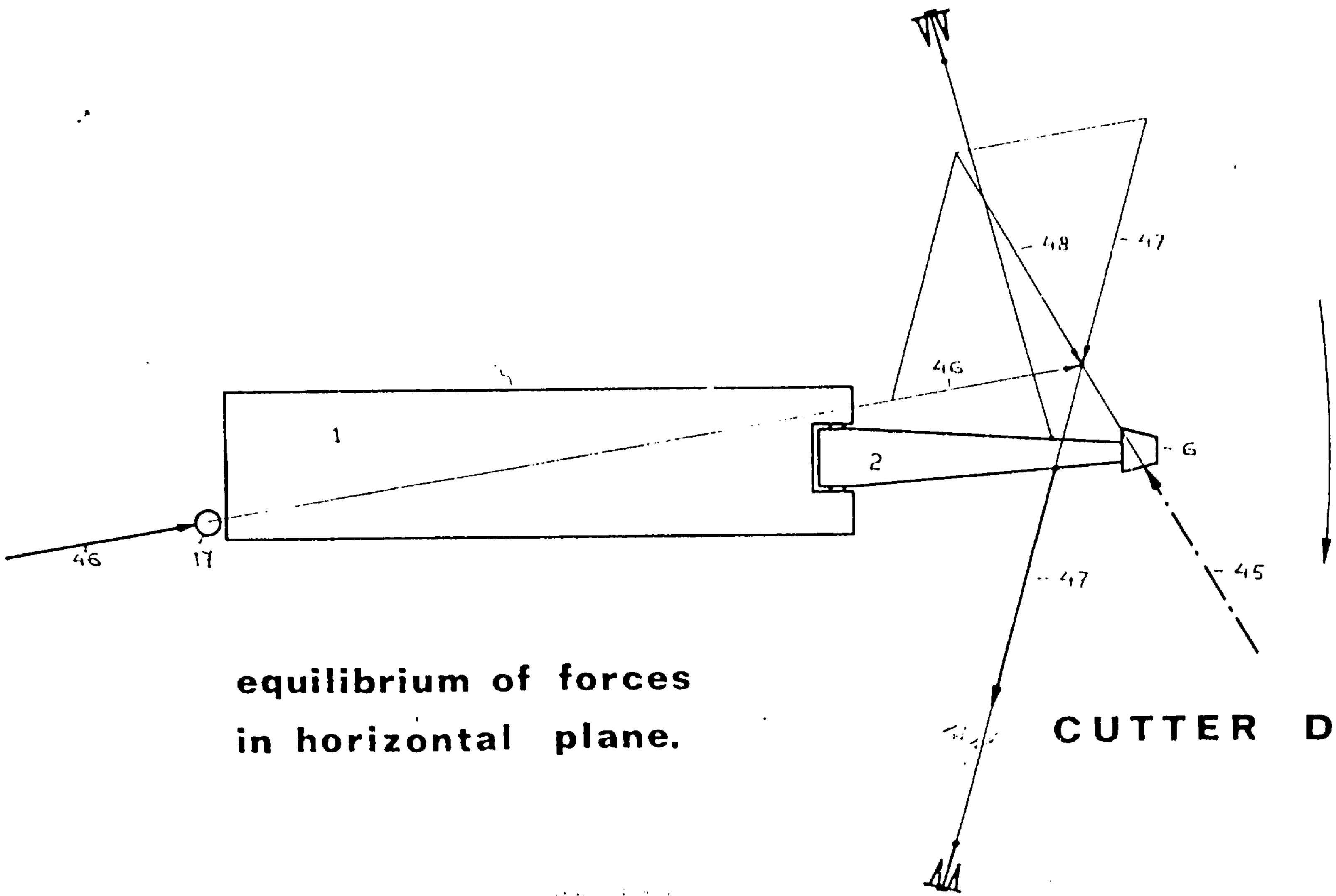
Swing to starboard, cutter rotates clockwise

1. Pontoon
2. Ladder
6. Cutter
17. Spudpole
22. Ladder gantry
41. Reaction force on tip of spudpole
42. Resultant of total weight and bouyancy forces
43. Resultant of 41 and 42
44. Forces on the cutter in the vertical plane

P.S. Of all forces only the component in the vertical plane is dealt with.

FIG. V-5.3.2

FIG. V. 5.3.3



equilibrium of forces in horizontal plane.

CUTTER DREDGER

V-5 CUTTER DREDGER

fig. V-5.3.3 Equilibrium of forces in the horizontal plane

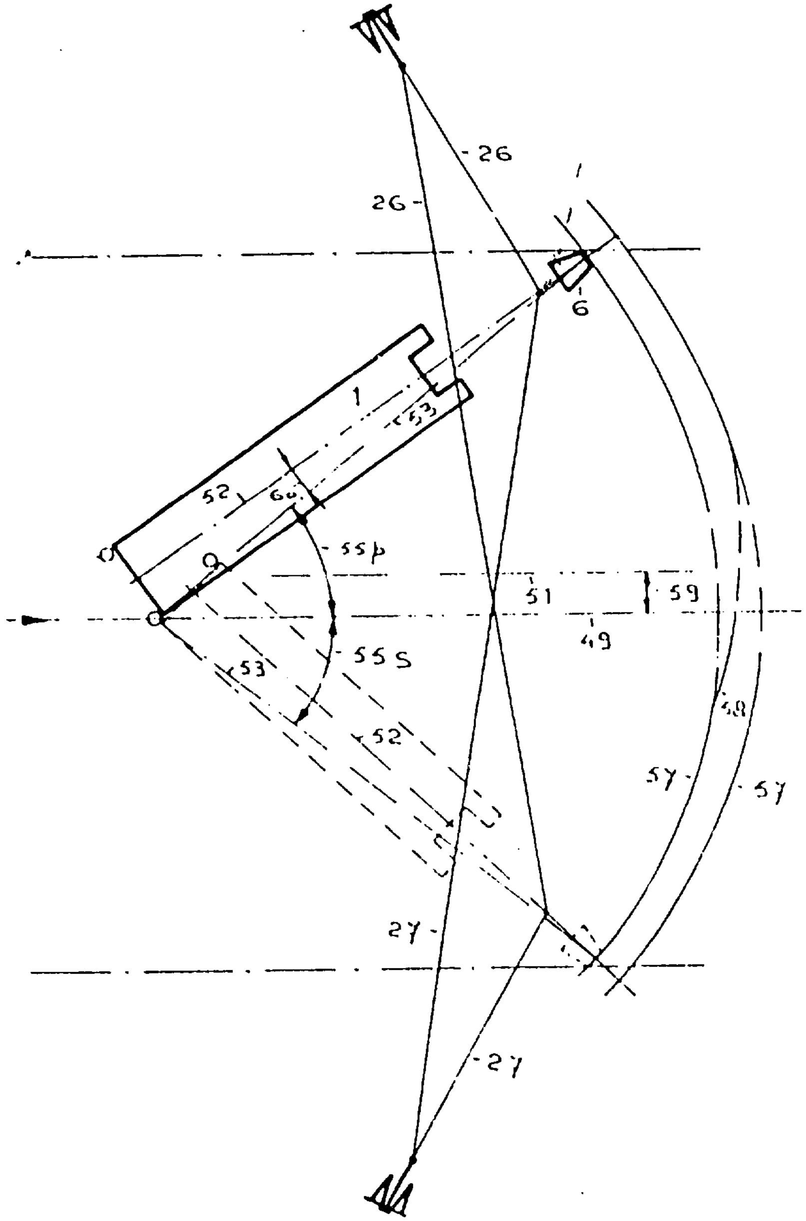
Swing to starboard, cutter rotates clockwise

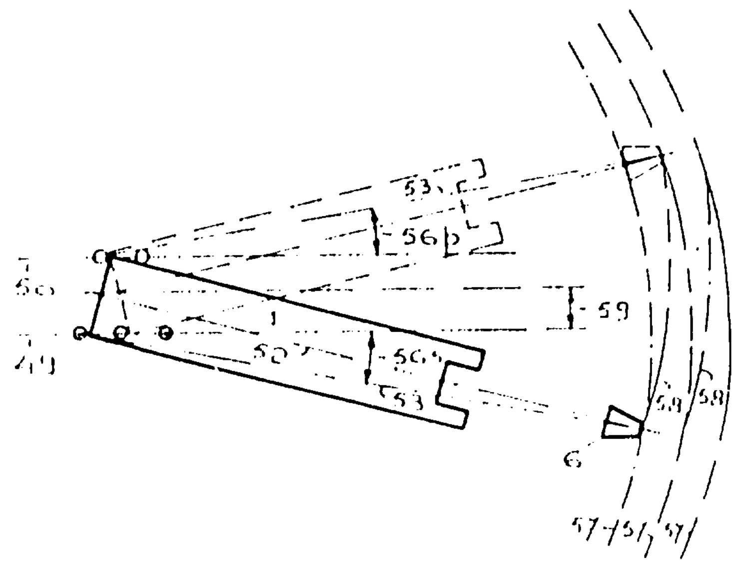
1. Pontoon
2. Cutter ladder
6. Cutter
17. Spudpole
45. Soil force on the cutter
46. Reaction force on the tip of the spudpole
47. Force in the starboard swing wire
48. Resultant of 46 and 47

P.S. Of all forces shown, only the component in the horizontal plane is dealt with.

FIG. V-5.3.3

FIG. V.5.4





CUTTER DREDGER

method of advancing along the
with the use of fixed spudpoles

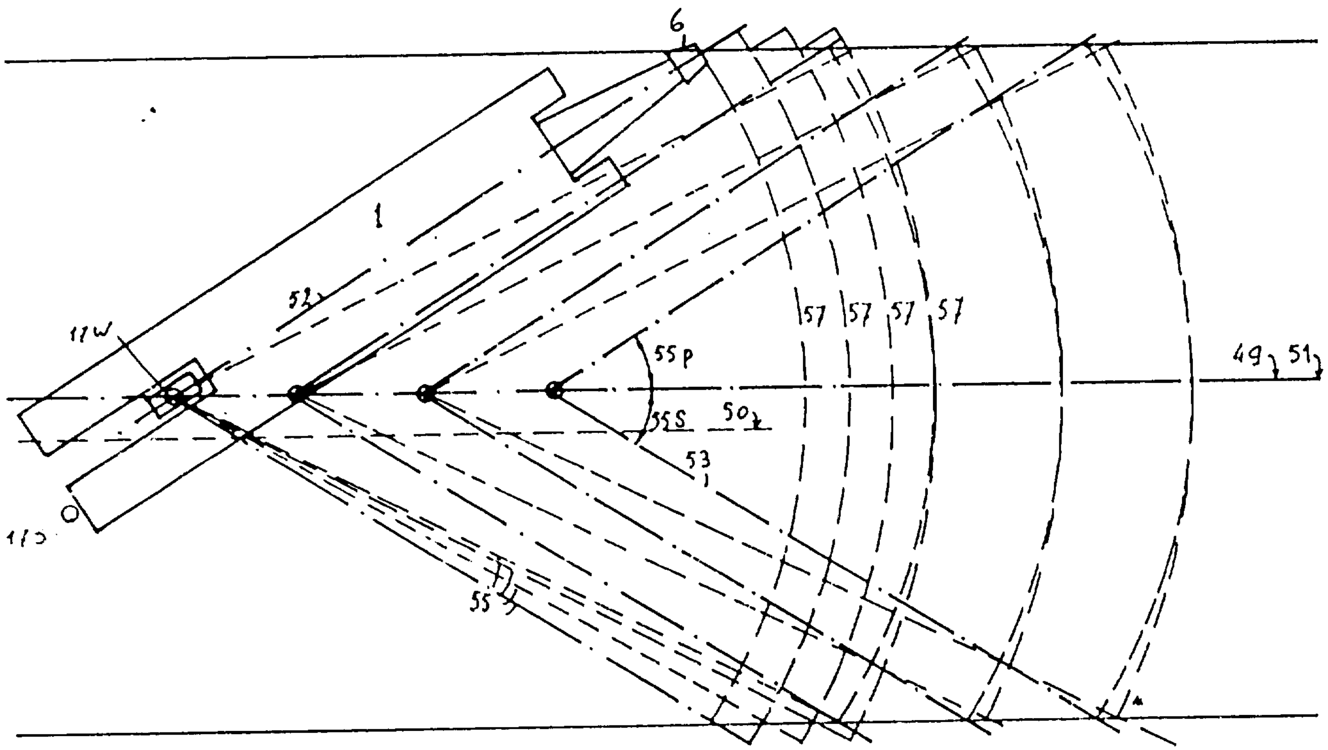
V-5 CUTTER DREDGER

fig. V-5.4 Method of advancing along the cut, using fixed spudpoles

1. Pontoon
6. Cutter
26. Port side wire
27. Starboard side wire
49. Path of the "working" spudpole - "working line"
50. Path of the "stepping" spudpole - "stepping line"
51. Centre line of dredger, when parallel to centre line canal, or "stake out line"
52. Centre line of dredger
53. Connecting line of cutter- working spudpole
55. Maximum swingangle during cutting
56. Angle whilst stepping
57. Contours of successive cuts
58. Path of the cutter during stepping
59. Distance between working line and stake out line (equals half the distance between /spudpoles)
60. Angle of correction between 52 and 55

FIG. V-5.4

FIG.V.5.5



CUTTER DREDGER

method of advancing along the cut with the use of spudcarriage

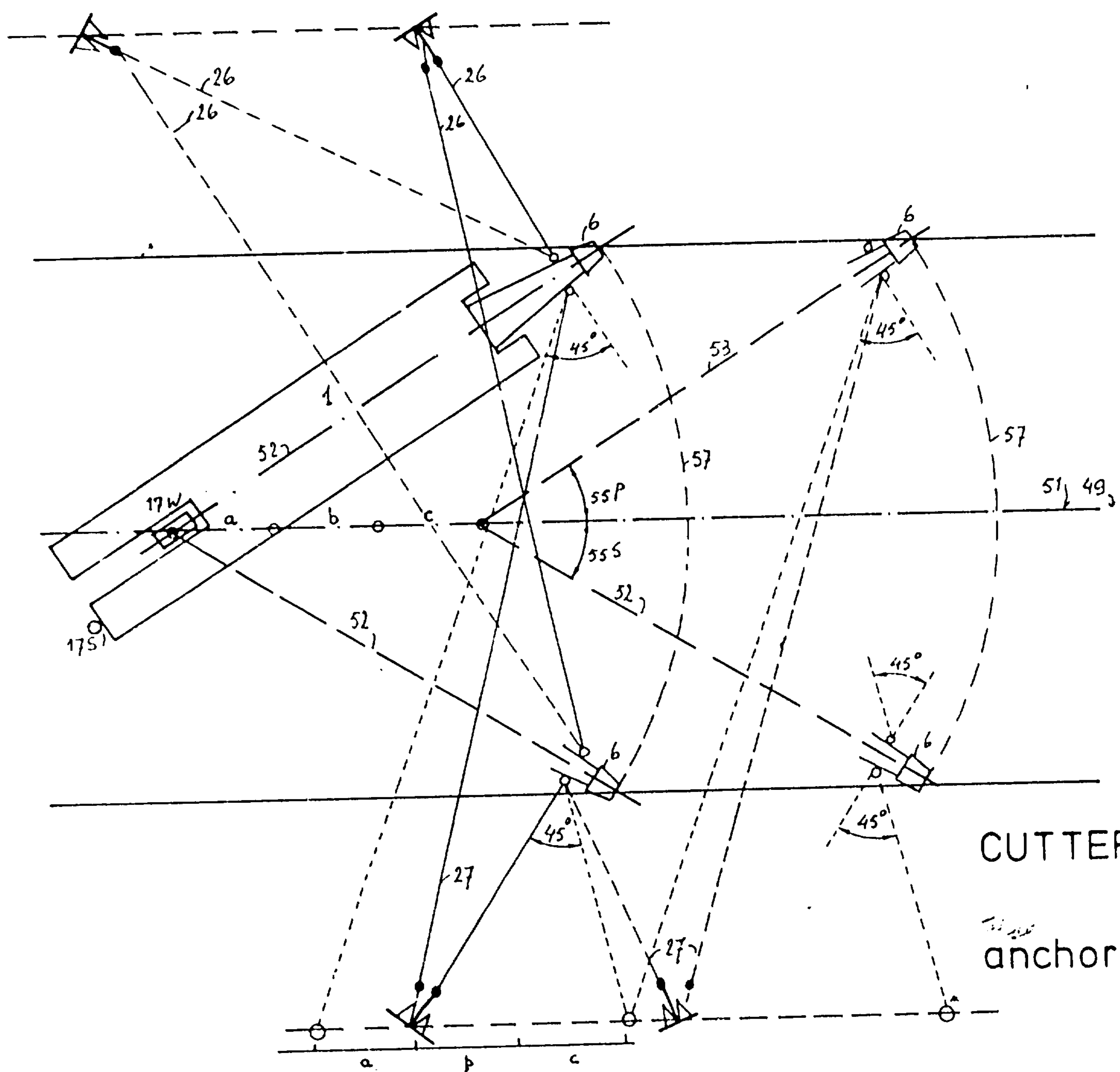
V-5 CUTTER DREDGER

fig. V-5.5 Method of advancing along the cut, using a spud carriage

1. Pontoon
6. Cutter
17w. "Working" spudpole in spud-carrier pushing the dredger forward when in centreline
17s. "Stepping" spudpole used when spud-carrier has pushed the dredger to its maximum /position and has to be brought forward
49. Path of the "working" spudpole - "working line"
50. Path of the "stepping" spudpole - "stepping line"
51. Centre line of dredger, when parallel to centre line canal, or "stake out line"
52. Centre line of dredger
55. Maximum swingangle during cutting
57. Contours of successive cuts

FIG. V-5.5

FIG. V.5.6.



CUTTER DREDGER

anchoring

V-5 CUTTER DREDGER

fig. V-5.6 Method of advancing along the cut, anchor positioning.

1. Pontoon

6. Cutter

26. Port side wire

27. Starboard side wire

49. Path of the "working" spudpole - "working line"

51. Centre line of dredger, when parallel to centre line canal, or "stake out line"

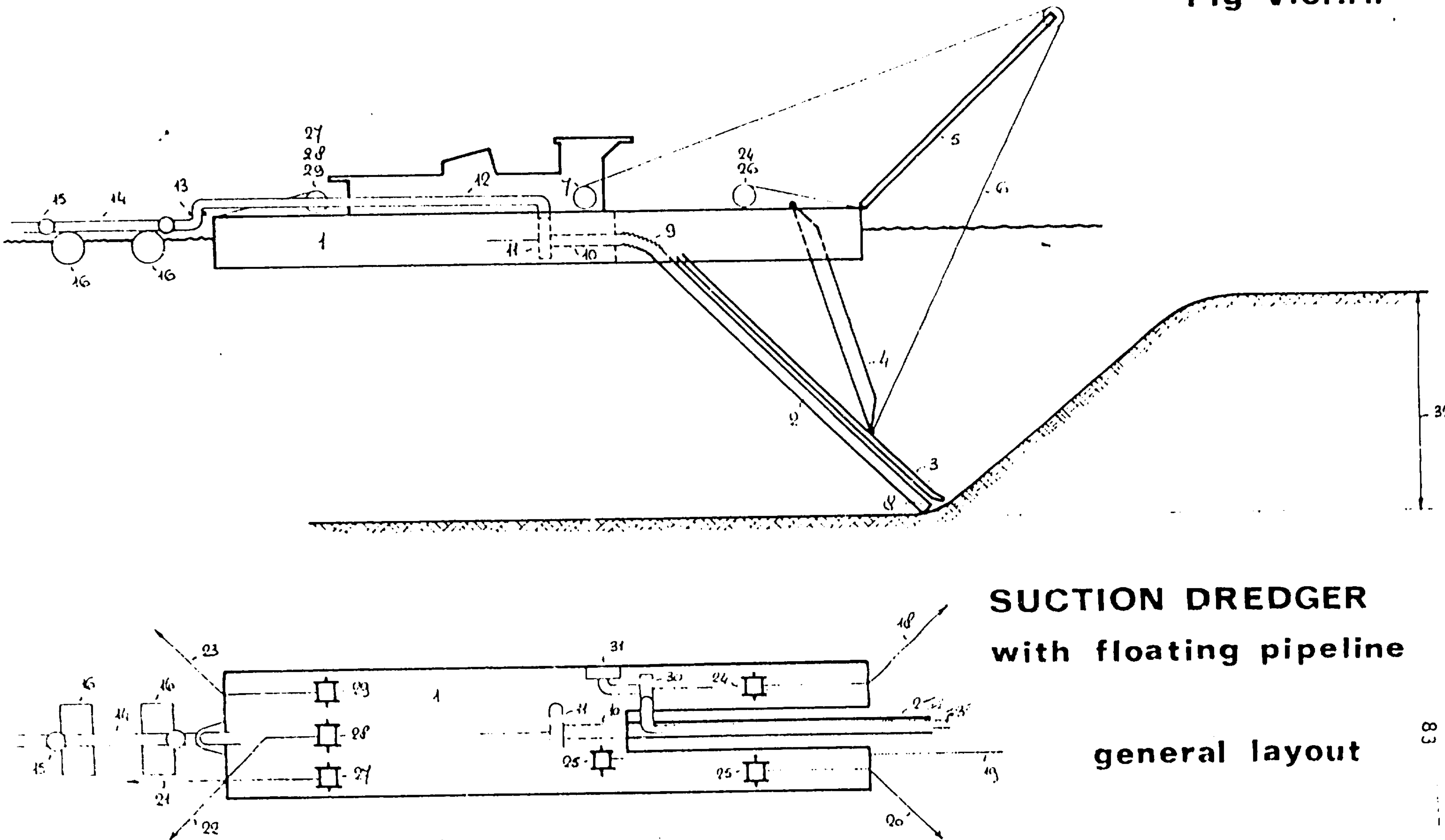
52. Centre line of dredger

53. Connecting line of cutter - working spudpole

55. Maximum swingangle during cutting

FIG. V-5.6

Fig V.6.1.1.



SUCTION DREDGER
with floating pipeline

general layout

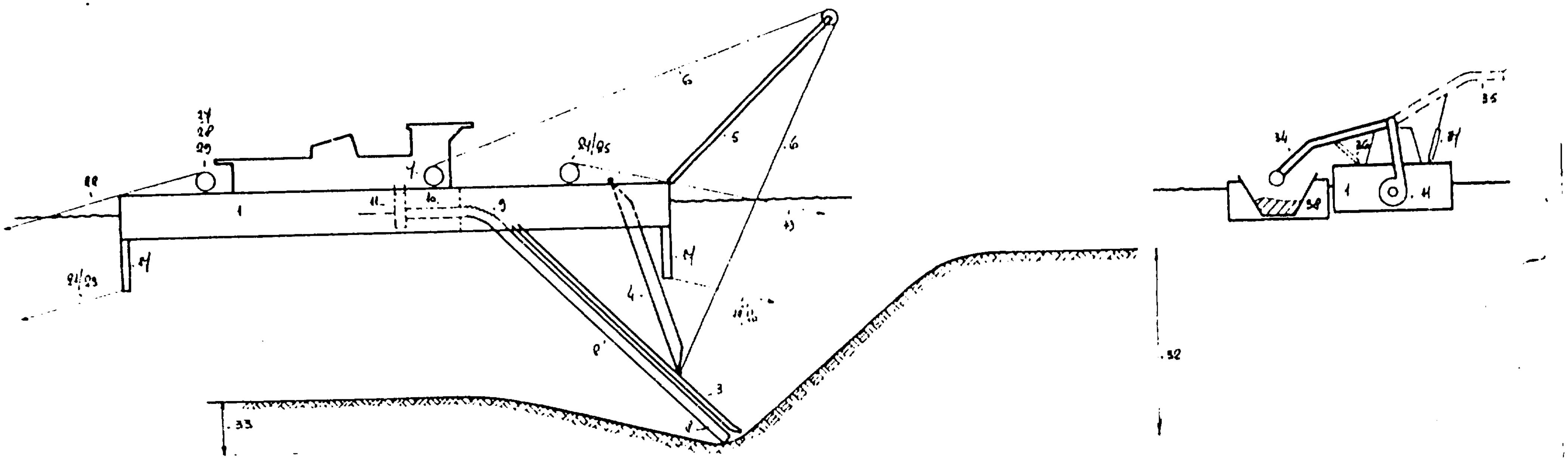
V-6 SUCTION DREDGER

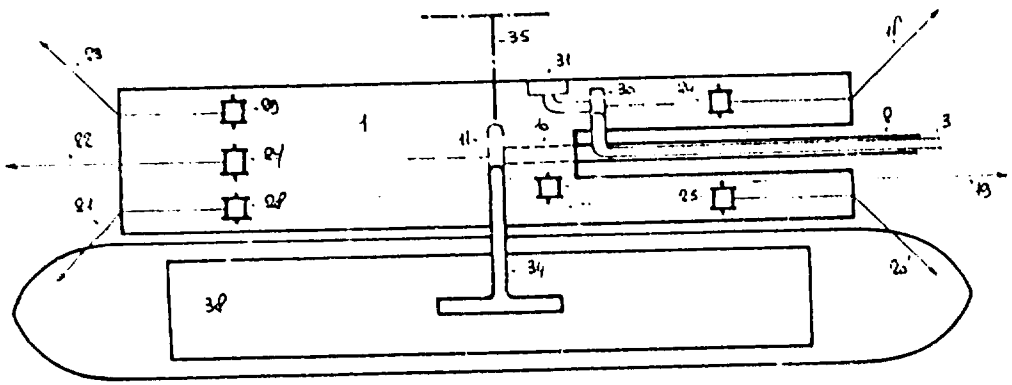
fig. V-6.1 General layout with floating pipeline.

1. Pontoon
2. Suction pipe
3. Water jet pipe
4. Suction pipe ladder
5. 'A' - frame
6. Suction hoist wire
7. Suction hoist
8. Suction orifice
9. Suction hose (suction sleeve)
10. Suction pipe in the vessel
11. Dredge pump
12. Discharge pipe (Discharge outlet (Am))
13. Swivel elbow("Goose neck" (Am))
14. Floating pipeline
15. Ball joints
16. Floats
18. Port forward side wire
19. Head main line
20. Starboard forward side wire
21. Aft main line
22. Starboard aft side wire
23. Port aft side wire
24. Port forward side winch
25. Starboard forward side winch
26. Head main winch
27. Aft main winch
28. Starboard aft side winch
29. Port aft side winch
30. Waterpump
31. Filter box in suction entrance for waterpump (sea chest)
32. Height of face

FIG. V-6.1.1

Fig. V.6.1.2.





SUCTION DREDGER
with barge-loading facilities

general layout

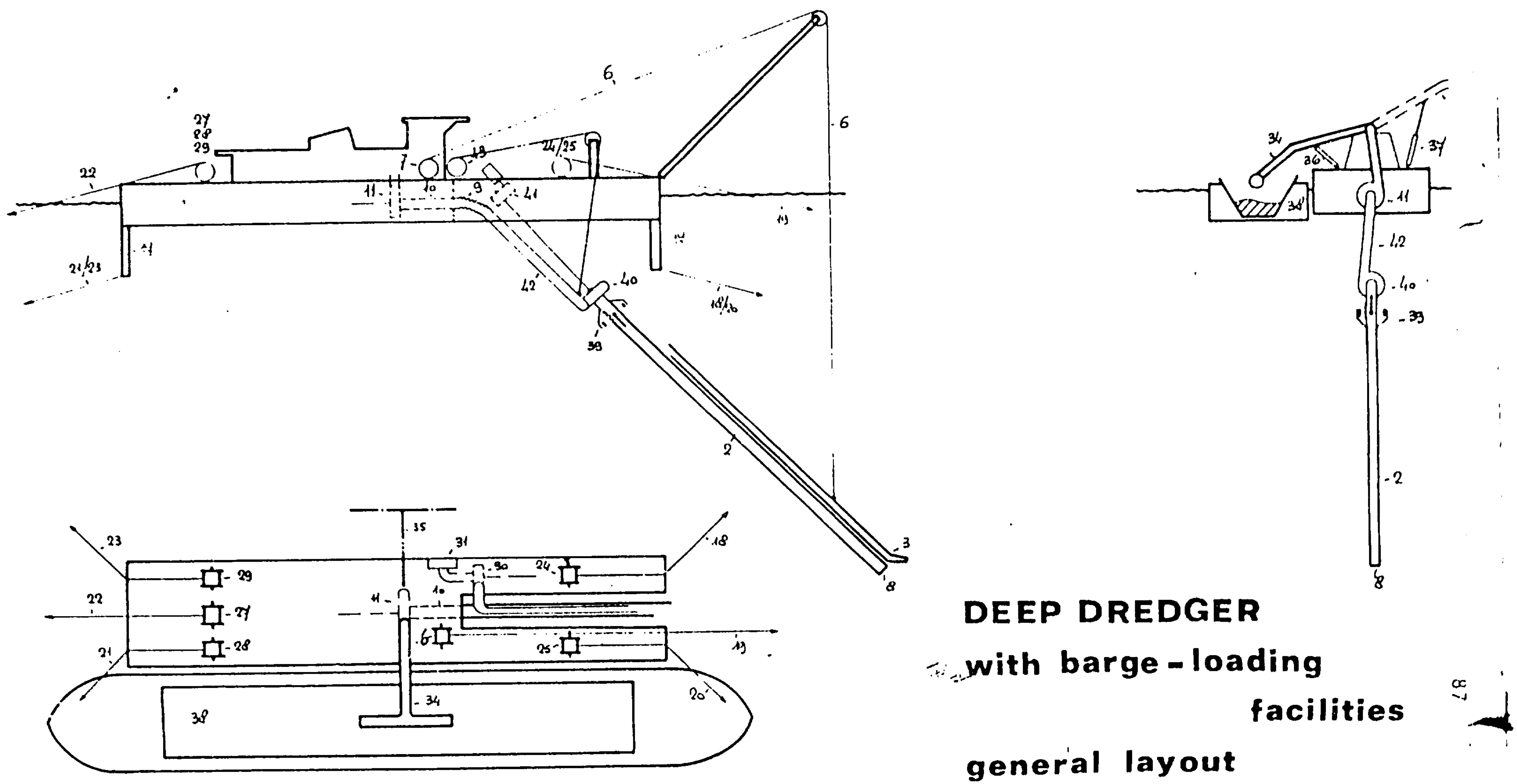
V-6 SUCTION DREDGER

fig. V-6.1.2 General layout with facilities for loading barges

1. Pontoon
2. Suction pipe
3. Water jet pipe
4. Suction pipe ladder
5. 'A'-frame
6. Suction hoist wire
7. Suction hoist winch
8. Suction orifice
9. Suction hose (suction sleeve (Am))
10. Suction pipe inside the vessel
11. Dredge pump
17. Under water fairleads
18. Port forward side wire
19. Head main line
20. Starboard forward side wire
21. Starboard aft side wire
22. Aft main line
23. Port aft side wire
24. Port forward side winch
25. Starboard forward side winch
26. Head main winch
27. Aft main winch
28. Starboard aft side winch
29. Port aft side winch
30. Waterpump
31. Filter for water pump (sea chest)
32. Height of face
33. Height of spillage
34. Starboard loading pipe; "spreader"
35. Port spreader
36. Hydraulic rams for manipulating spreaders
37. As 36
38. Barge

FIG. V-6.1.2

Fig. V.6.1.3.



DEEP DREDGER
with barge-loading facilities
general layout

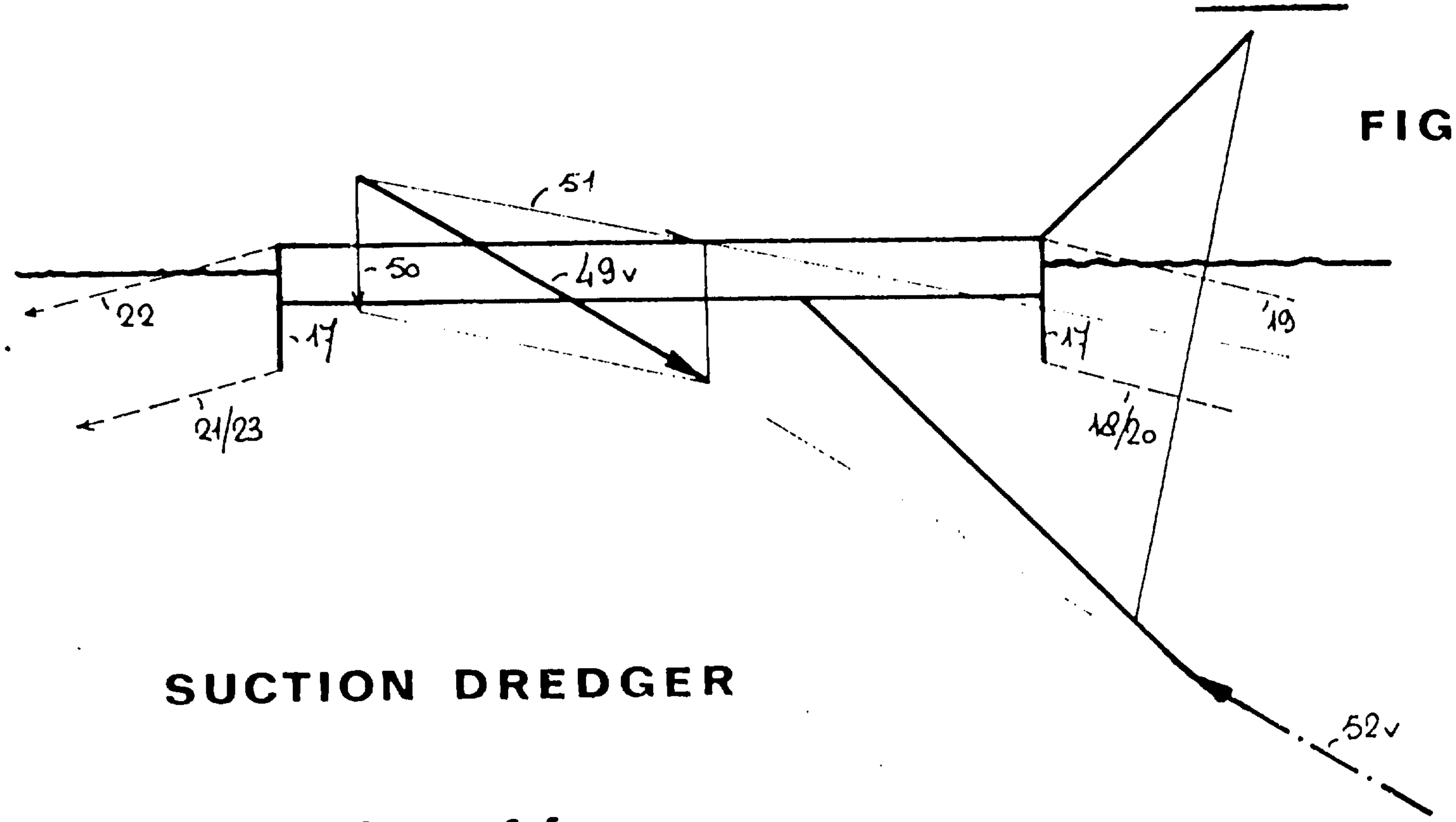
V-6 DEEP DREDGER

fig. V-6.1.3 General lay-out; with facilities for loading barges

1. Pontoon
2. Suction pipe
3. Water jet pipe
6. Suction hoist wire
7. Suction hoist winch
8. Suction orifice
9. Suction hose (Suction sleeve(Am))
10. Suction pipe inside the ship
11. Dredge pump
17. Underwater fairleads
18. Port forward side wire
19. Head main line
20. Starboard forward side wire
21. Starboard aft side wire
22. Aft main wire
23. Port aft side wire
24. Port forward side winch
25. Starboard forward side winch
26. Head main winch
27. Aft main winch
28. Starboard aft side winch
29. Port side aft winch
30. Pump for water jet
31. Sea chest
34. Starboard spreader
35. Port spreader
36. Hydraulic ram for manipulating spreader
37. As 36
38. Barge
39. Universal joint in suction pipe
40. Under-water pump
41. Electric motor and gear box for under-water pump
42. Discharge pipe leading from under-water pump
43. Hoist for under-water pump assembly

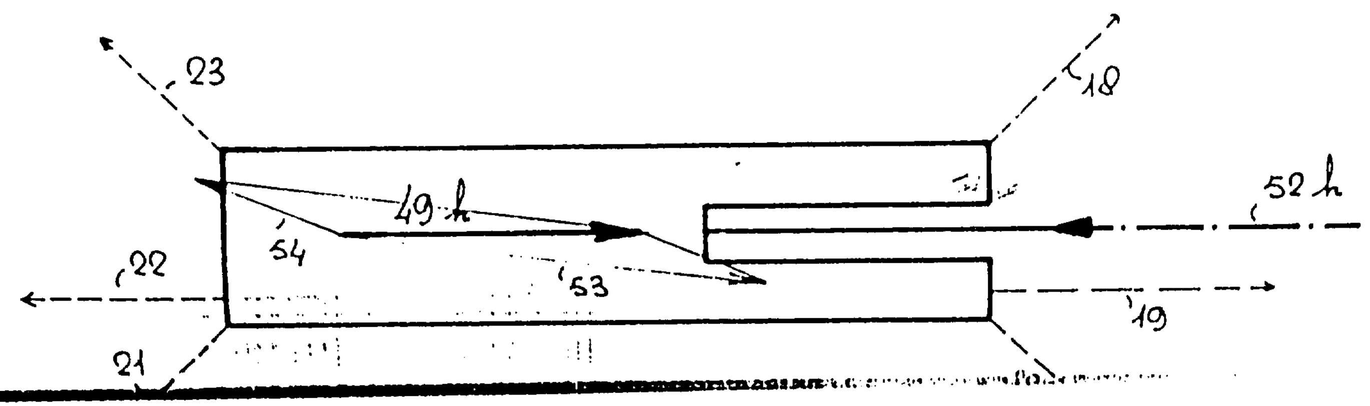
FIG. V-6.1.3

FIG. V. 6.2.



SUCTION DREDGER

equilibrium of forces



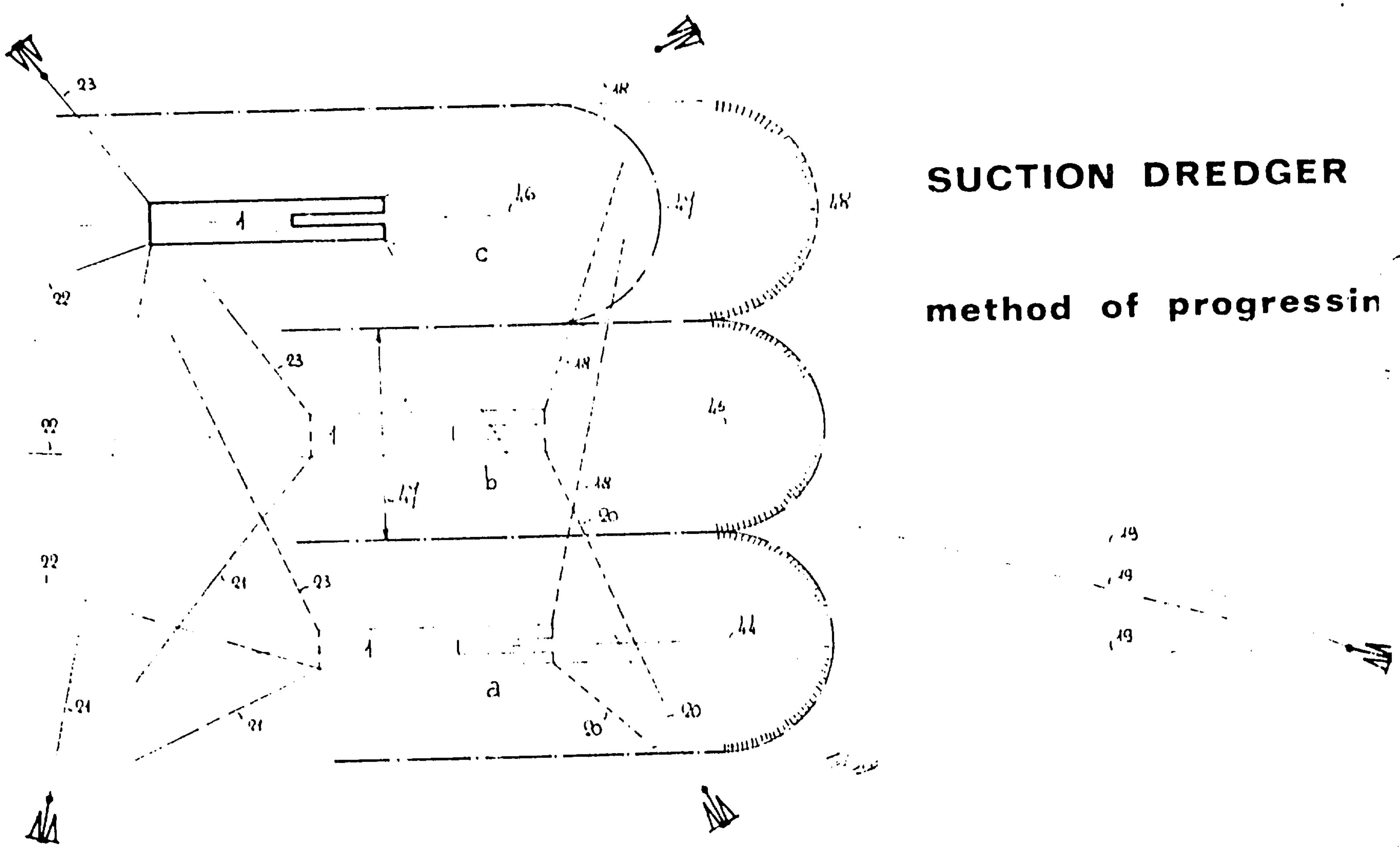
V-6 SUCTION DREDGER

fig. V-6.2 Equilibrium of forces.

17. Under-water fairleads
18. Port forward side wire
19. Head main line
20. Starboard forward side wire
21. Starboard aft side wire
22. Aft main wire
23. Port aft side wire
50. Resultant of weight of vessel and displacement forces
51. Resultant, in the vertical plane, of forces in wires
49v. Resultant of 50 and 51
52v. Resultant, in the vertical plano, of the digging forces
53. Resultant, in the horizontal plane. of all forces in wires on bow section
54. Resultant, in the horizontal plane, of all forces in wires on the stern section
49h. Resultant of 53 and 54
52h. Resultant; in the horizontal plane of the digging forces

FIG. V-6.2

Fig. V.6.3.



SUCTION DREDGER

method of progressin

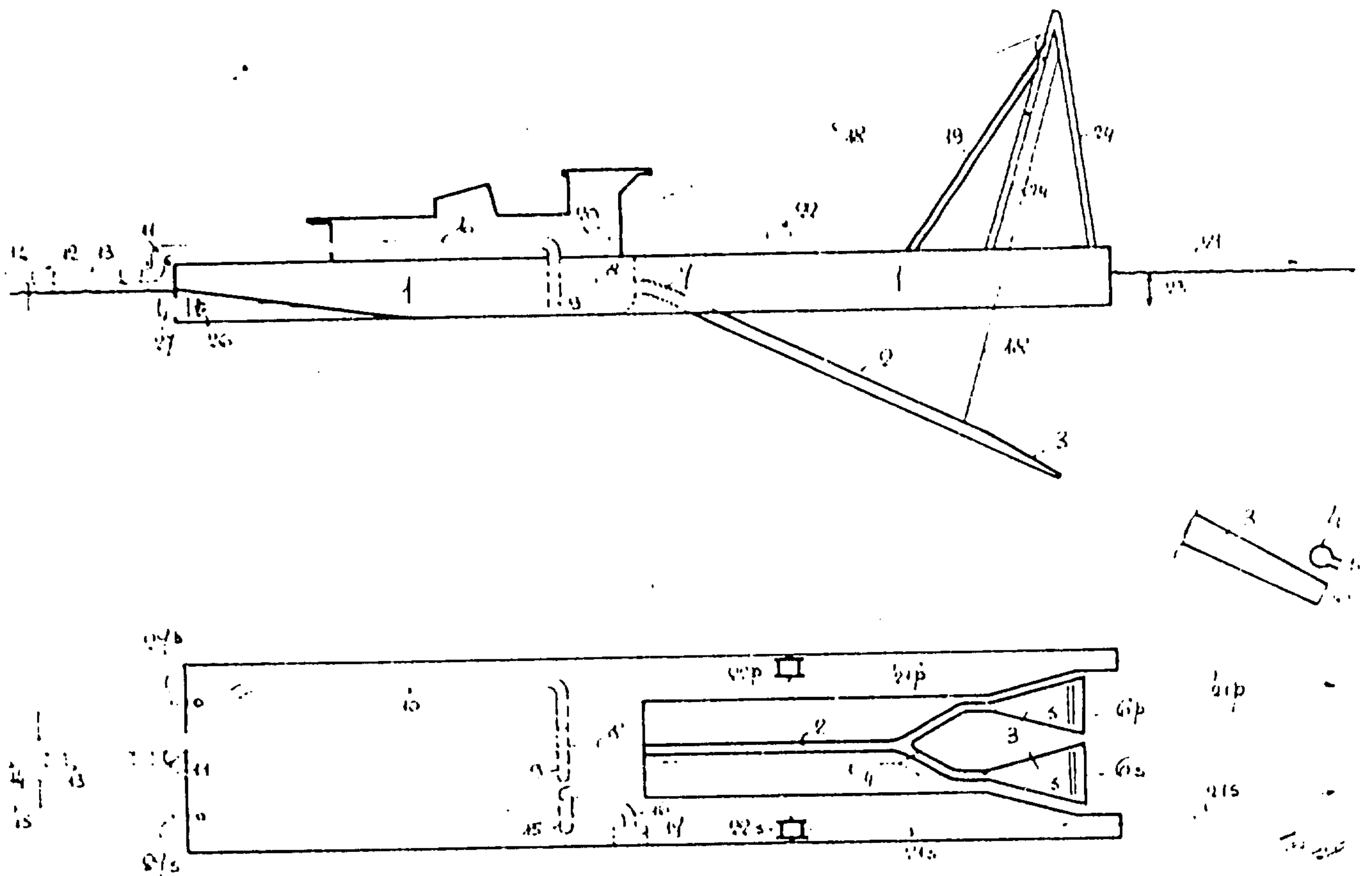
V-6 SUCTION DREDGER

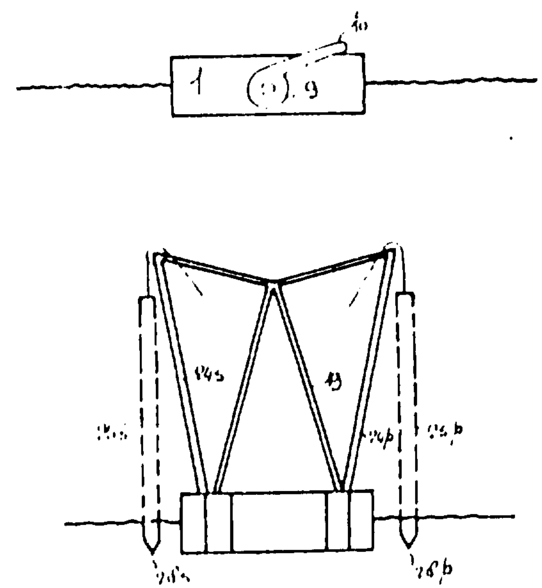
fig. V-6.3 Method of progressing in relation to the shape of the face

1. Dredger
18. Port forward side wire
19. Head main line; the anchor to be placed in such a way, that the wire runs clear / of the suction pipe; also when the pipe is raised !
20. Starboard forward side wire
21. Starboard aft side wire
22. Aft main line
23. Port aft side wire
44. Centre line of cut a.
45. Centre line of cut b.
46. Centre line of cut c.
47. Momentary boundary of the face
48. Outline of the face after some time. (say: after one week)

FIG. V-6.3

Fig. V.7.1.





DUSTPAN DREDGER

general layout

V-7 DUSTPAN DREDGER

fig. V-7.1 Plan and elevations

1. Ship
2. Suction tube
3. Two separate dustpan heads, parallel connected to the suction tube
4. Manifold for the clean-water-jets
5. Jets
6. Opening of the dustpan head, appr. 40 cm high, a few meters wide.
7. Suction hose
8. Suction pipe inside the ship
9. Dredge pump
10. Discharge pipe from dregde pump
11. Swivel elbow (Goose neck)
12. Ball joint
13. Suspended pipe section
14. Floating pipe section
15. Pump for clean water for the jets nr. 5
16. Suction pipe for nr. 15
17. Filter for nr. 15 (sea chest)
18. Suction pipe wire
19. Suction pipe gantry
20. Suction pipe hoist
21. Head line
22. Head winch
23. Low draught of the vessel (1,50 m) in view of shallow bars
24. 'A'- frame for holding and placing of the jet-poles
25. Jet-pole (jetted in the river bed, for use as anchorage
26. Ships propeller
27. Rudder
28. Jet shaped point of the anchor pole
35. Floats for the floating pipe line

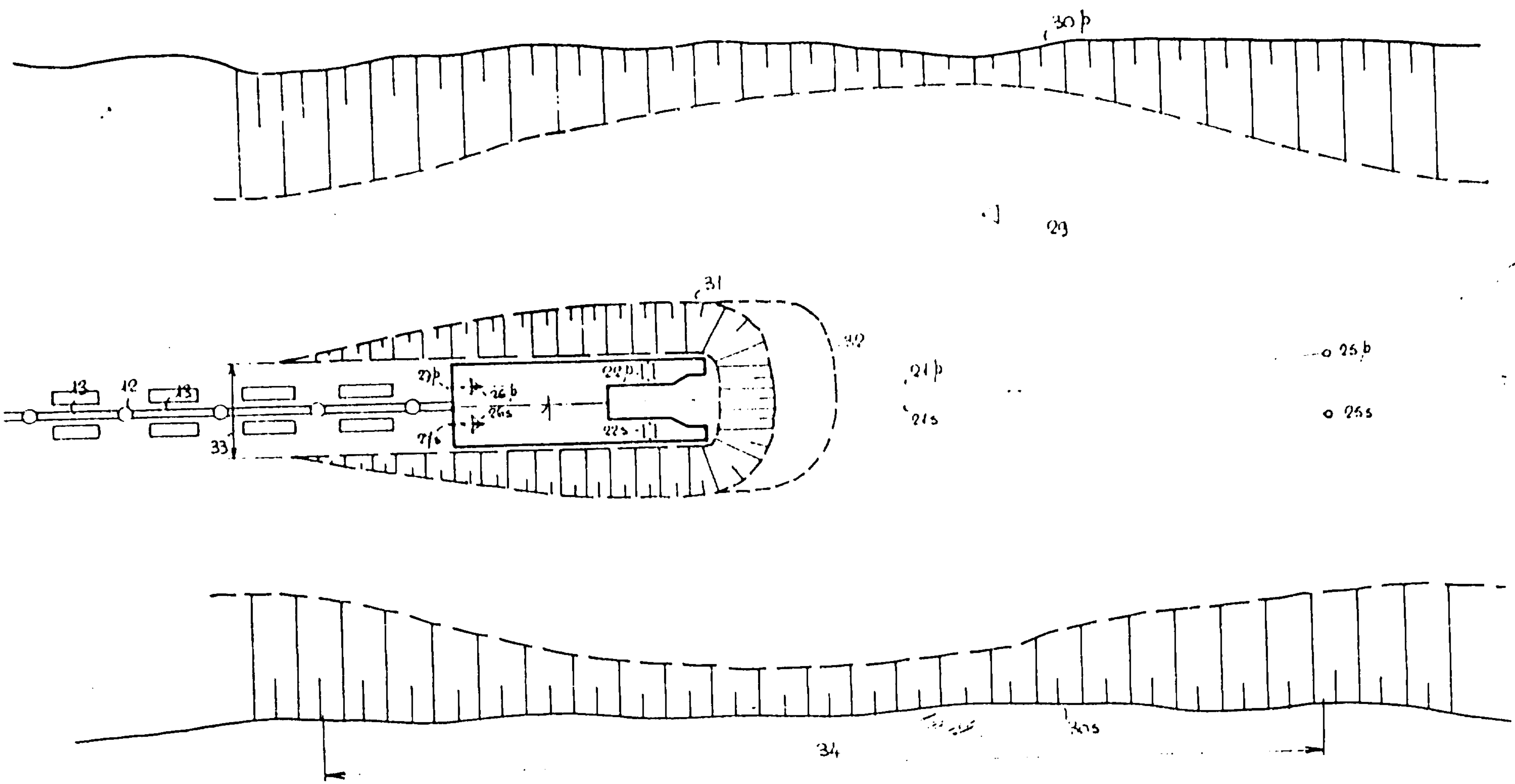
p = port

s = starboard

FIG. V-7.1

Fig. V. 7. 2.

DUSTPAN DREDGER



method of progressing

V-7 DUSTPAN DREDGER

fig. V-7,2 Method of progressing

1. Ship
12. Ball joint
13. Floating pipe line
21. Head lines
22. Head winches
25. Anchor poles, jetted into the river bed
26. Propeller
27. Rudder
29. Prevailing direction of current
30. River embankment
31. Boundary of the cut
32. Boundary of the cut, after the dredger has made some progress
33. Bottom width of the cut
34. Length of the shallow area to be dredged

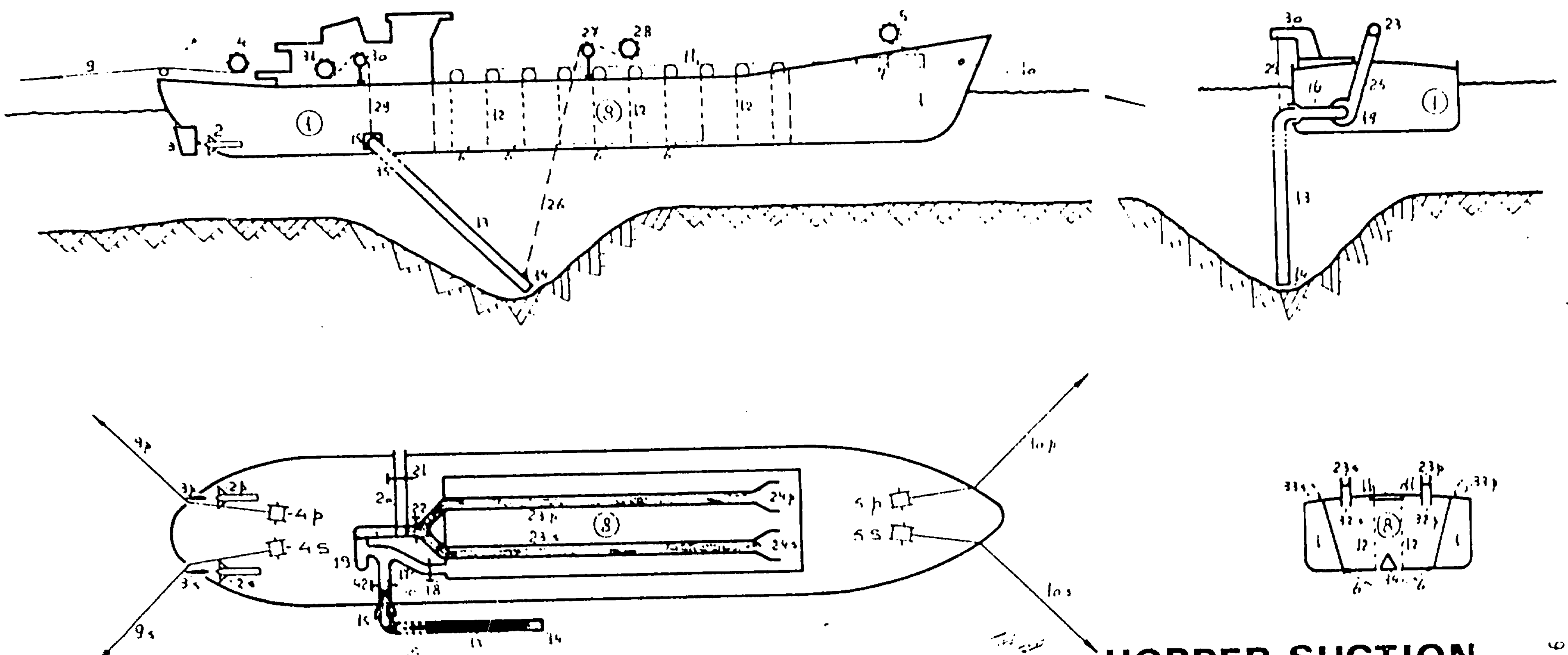
p= port
s= starboard

P.S. After the dredger has completed the cut as shown on this sketch, the improved currents are supposed to scour out the rest of the bar. (Korea -effect)

This type of dredger is used practically only in the United States of America, on the Mississippi river.

Fig. V-7.2

FIG. V. 8.1.



HOPPER SUCTION DREDGE

general layout

V-8 SEAGOING STATIONARY HOPPER SUCTION DREDGER

fig. V-8.1 General plan.

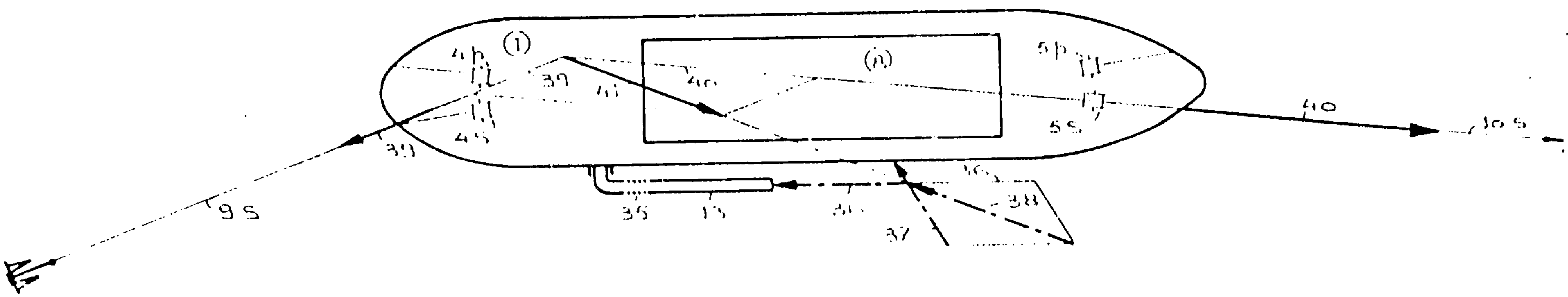
1. Ship
2. Propeller
3. Rudders
4. Aft anchor winches
5. Forward anchor winches
6. Hopper doors
7. Hydraulic rams for operating the hopper doors
8. Hopper
9. Aft anchor wire
10. Forward anchor wire
11. Horizontal door hoisting bar on rollers, operating nrs 12.
12. Hopper door chains
13. Suction tube
14. Suction orifice
15. Suction pipe trunnion & slide
16. Pipeline in ship, connecting the suction pipe and the dredge pump
17. Pipeline in the ship, connecting the hopper and the dredge pump
18. Valve in suction from hopper
19. Dredge pump
20. Overboard discharge pipe
21. Valve in 20
22. Valve in pipe from pomp to hopper
23. Lander (Discharge distribution pipe or chute)
24. Fishtail (end of lander)
25. Riser (Discharge pipe on dredge pump)
26. Suction orifice hoist wire
27. Gantry for no 26
28. Suction tube hoist
29. Trunnion hoisting wire
30. Gantry for no 29
31. Hoisting winch for no 29
32. Lander discharge, equipped with regulating valve
33. Overflow (adjustable) of the hopper
34. Center keelson
35. Rubber hose in suction pipe, built in a universal joint with no 15
42. Main suction valve

p = port

s = startboard

FIG. V-8.1

FIG. V.8.2.



HOPPER SUCTION DREDGER

equilibrium of forces
whilst dredging

V - 8 SEAGOING STATIONARY HOPPER SUCTION DREDGER

fig. V-8.2 Equilibrium of forces during dredging operations

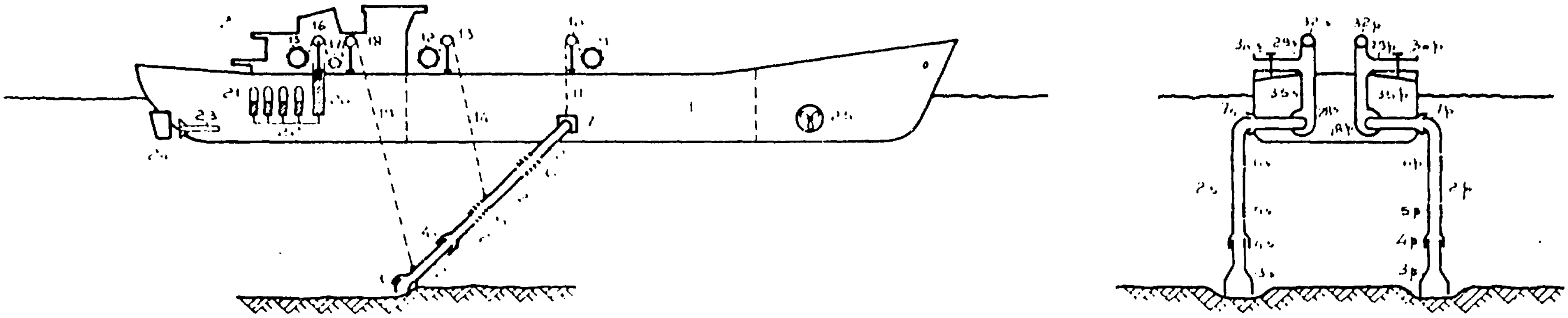
1. Ship
4. Aft anchor winches
5. Forward anchor winches
8. Hopper
9. Aft anchor wire
10. Forward anchor wire
13. Suction pipe
35. Suction hose
36. Horizontal component of forces on suction mouth
37. Resultant of current- and wind forces
38. Resultant of 36 and 37
39. Reaction force in aft anchor wire
40. Reaction force in forward anchor wire
41. Resultant of 39 and 40

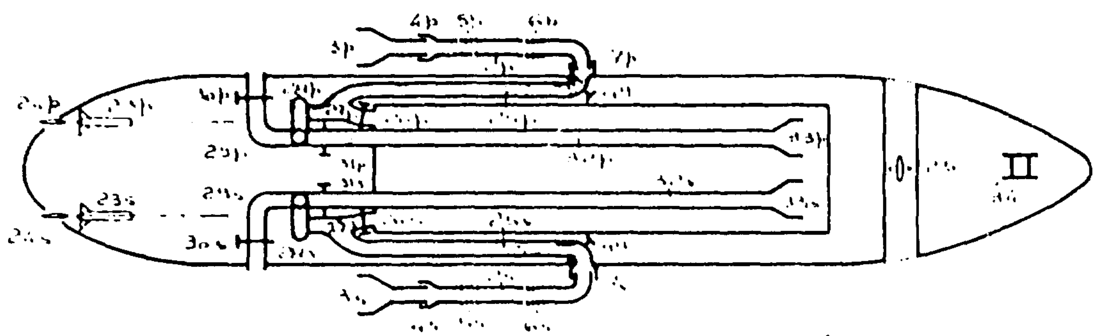
p = port

s = starboard

FIG. V-8.2

FIG. V.9.1.





TRAILING HOPPER SUCTION DREDGER

general arrangement of the dredging installations

V-9 TRAILING HOPPER SUCTION DREDGER (TRAILER)

fig. V-9.1 General plan of the dredging facilities

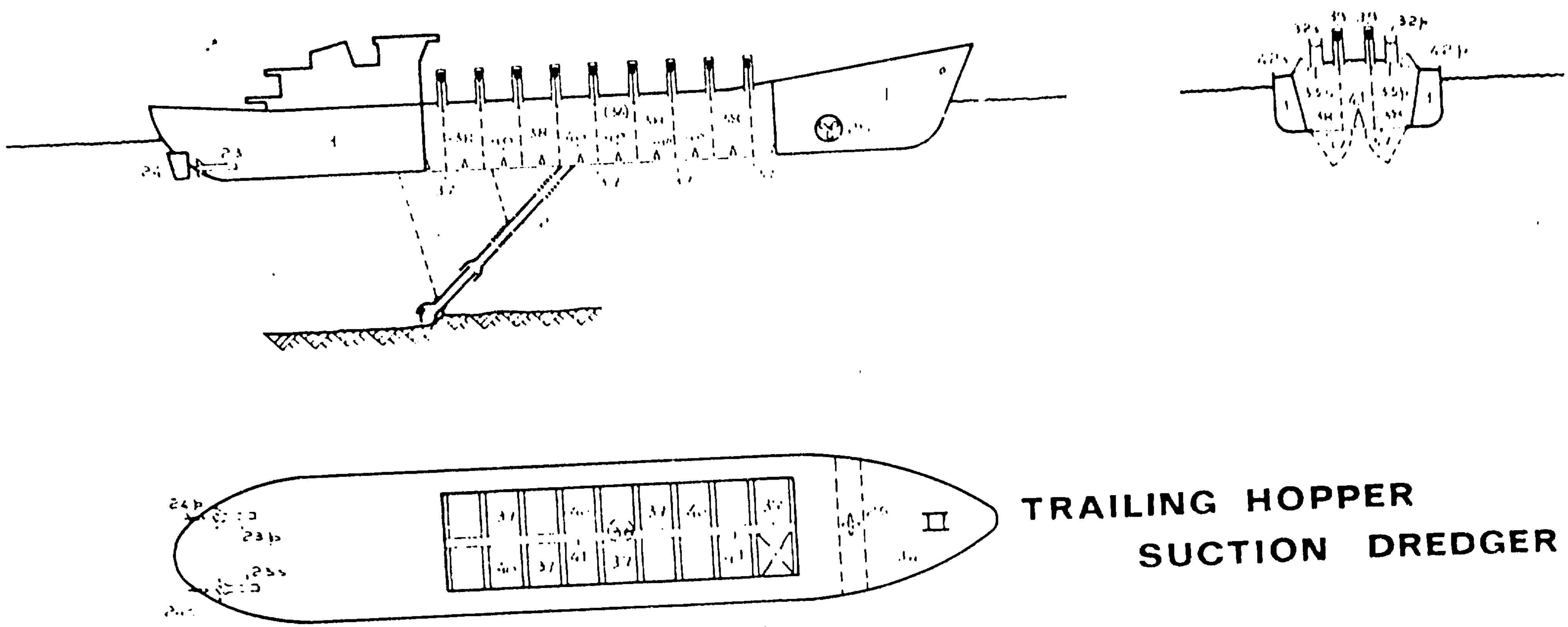
1. Ship
2. Sections of the trailing suction tube
3. Self adjusting trailing head (Drag)
4. Pirot joint in suction tube to eliminate the effect of the roll of the ship and uneven bottom
5. Universal joint, with built in suction hose
6. Hinged joint with built in suction hose
7. Trunnion bend and slide
9. Trunnion hoist winch
10. Trunnion hoist gantry
11. Trunnion hoist wire
12. Intermediate gantry winch
13. Intermediate gantry
14. Intermediate hoist wire
15. Drag winch
16. Swell compensator sheave
17. Sheave
18. Drag gantry
19. Drag wire
20. Swell compensator ram
21. Swell compensator pressure vessels, filled with oil and air
22. Manifold between pressure vessels. Each vessel can be connected separately
23. Ships propellers
24. Rudders
25. Bow thrust unit

25s/25p Suction pipe from trailing pipe to dredge pu mp

26. Hopper suction valves
27. Hopper suction pipes
28. Dredge pumps
29. Overboard - waste discharge pipe
30. Valve in no 29
31. Lander discharge valves
32. Lander (discharge distribution pipe or chute equipped with valves to establish an even fill of the hopper)
33. Fishtail
34. Forward windlass
35. Risers on dredge pumps (pump discharge pipes)
49. Main suction va lves.

FIG. V-9.1

FIG. V. 9. 2.



TRAILING HOPPER SUCTION DREDGER

general arrangement of the hopper installation

V-9 TRAILING HOPPER SUCTION DREDGER

fig. V-9.2 General plan of the hopper facilities

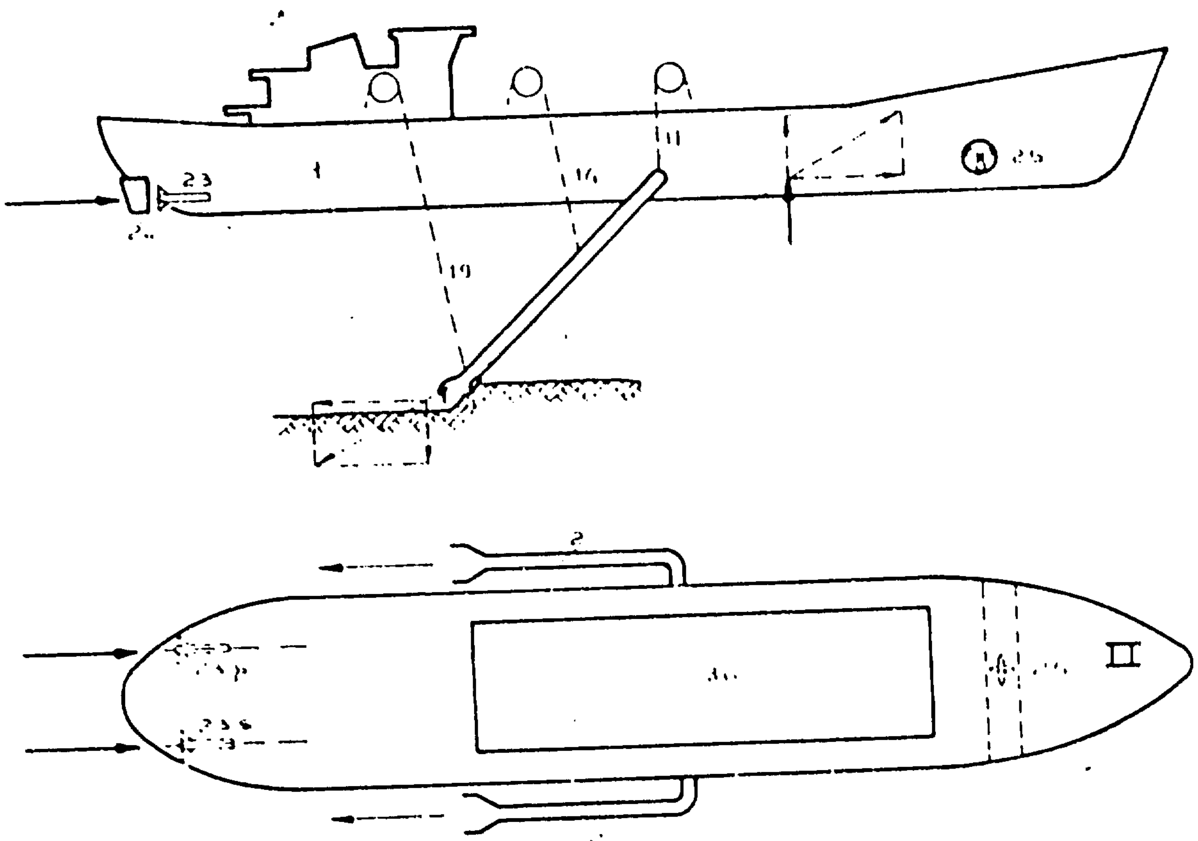
1. Ship
2. Trailing suction tube
23. Propeller
24. Rudder
32. Lander
33. Lander discharges with valves
34. Forward windlass
36. Hopper
37. Hopper doors
38. Hopper doorchains
40. Cross keelsons
41. Center keelson
42. Adjustable hopper overflow weirs

p = port

s = starboard

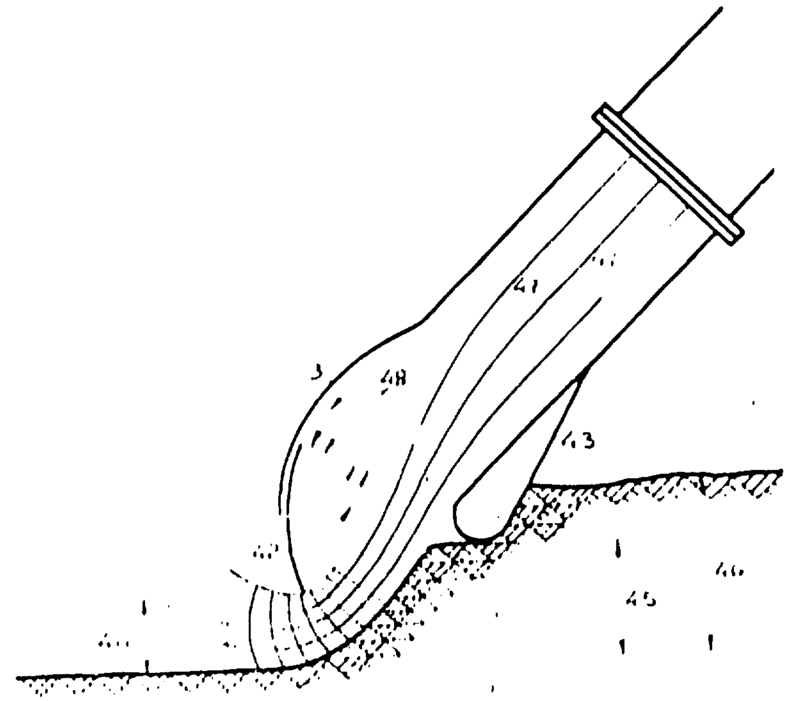
FIG. V-9.2

Fig. V.9.4.



equilibrium of forces

Fig. V.9.3.



technique of scouring by suction through draghead

TRAILING HOPPER SUCTION DREDGER

V-9 TRAILING HOPPER SUCTION DREDGER

fig. V-9.4 Equilibrium of forces in the vertical and horizontal plane

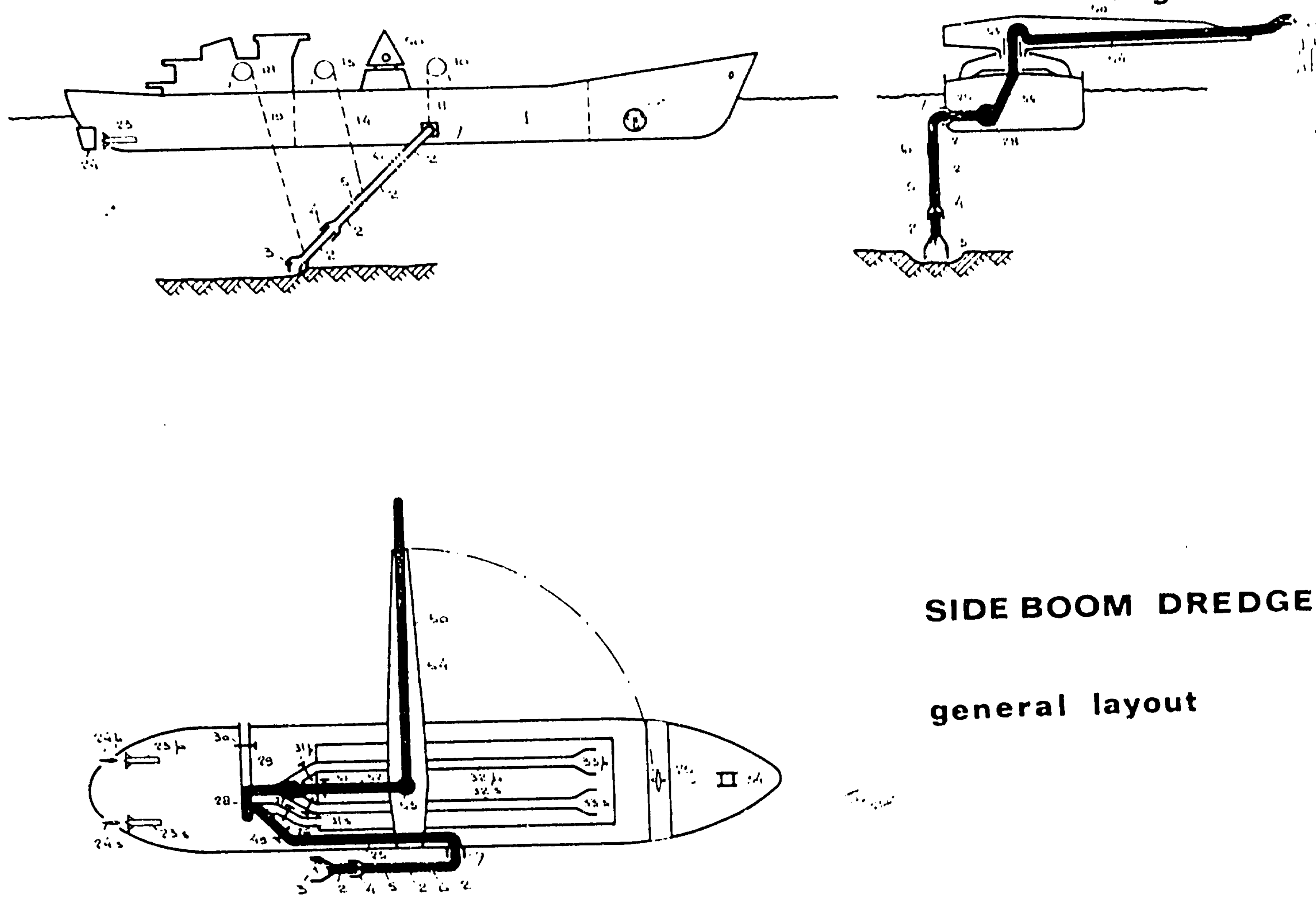
1. Ship
2. Trailing suction tube
3. Drag
11. Elbow trunnion & slide hoist wire
14. Intermediate hoist wire
19. Drag hoist wire
23. Propellers
24. Rudders
25. Bow thrust unit
36. Hopper

fig. V-9.3 Technique of the disintegration of the soil and intake of the spoil

2. Trailing suction tube
3. Drag (Trailing suction orifice)
42. Self adjusting visor of drag
43. Heel of the drag
44. Adjustable water opening underneath the visor (suction slit)
(Height to adjust according to the type of soil to be dredged)
45. Height of the cut eroded by the waterflow
46. Total height of cut
47. Stream line
48. Vortex guiding the stream of the slurry

FIG. V-9.3
V-9.4

Fig. V. 10.1.



SIDE BOOM DREDGER

general layout

V-10 SIDE BOOM DREDGER

fig. V-10.1 General plan - elevation - cross section

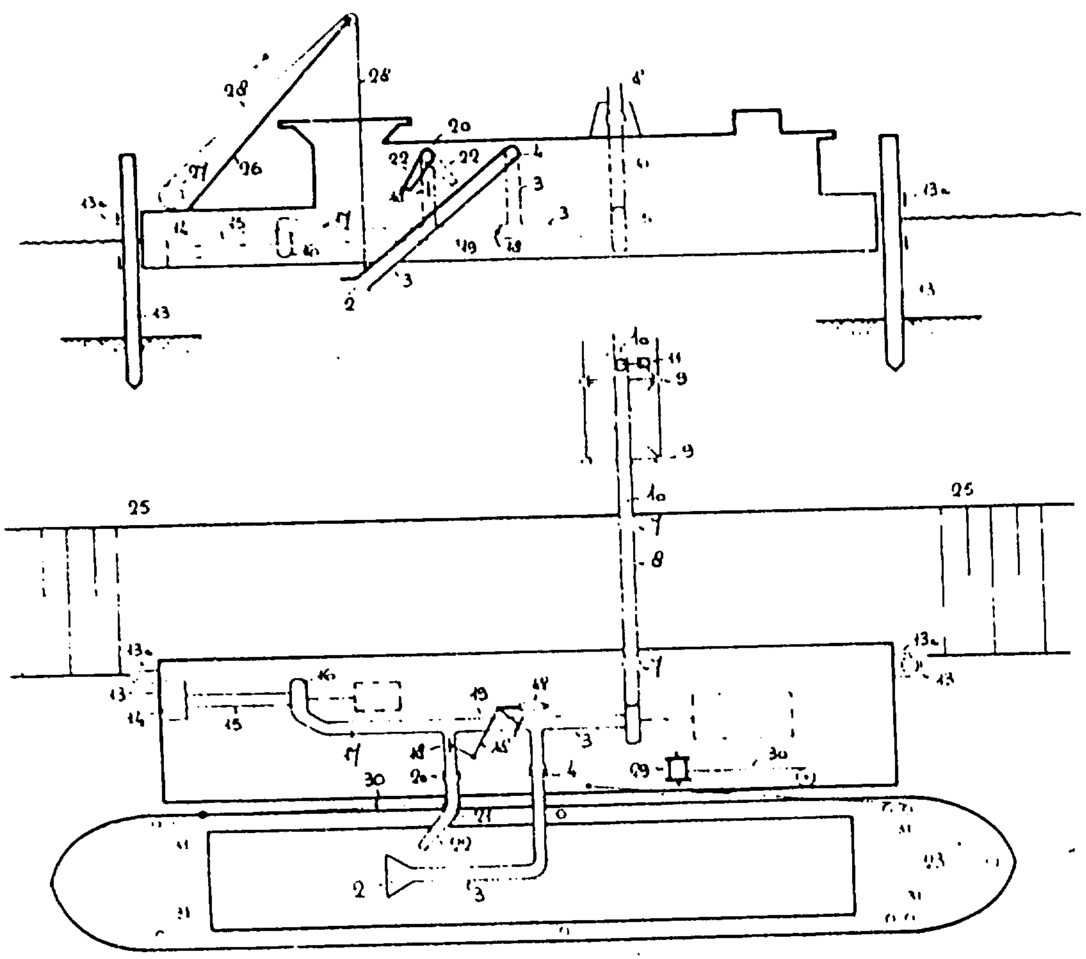
1. Ship
2. Trailing suction tube
3. Drag (Trailing suction head)
4. Pivot joint in suction tube
5. Suction hose in universal joint
6. Suction hose in vertical hing joint
7. Elbow trunnion & slide
10. Elbow trunnion & slide gantry
11. Elbow trunnion & slide hoist wire
13. Intermediate gantry
14. Intermediate hoist wire
18. Drag gantry (aft gantry)
19. Drag hoist wire, via swell compensator
23. Propellers
24. Rudders
25. Suction pipe aboard ship
26. Suction pipe to hopper
27. Valve in no 26
28. Dredge pump
29. Overboard waste discharge pipe
30. Valve to no. 29
31. Valves in discharge pipes to hopper
32. Landers
33. Fishtails (ends of landers)
34. Forward windlass
35. Risers on dredge pump.
49. Valve in suction pipeline
50. Turnable support for side boom discharge pipe
51. Valve in discharge through side boom
52. Connection pipe to side boom
53. Revolving joint in discharge pipe
54. Side boom pipe line
55. Bow thruster

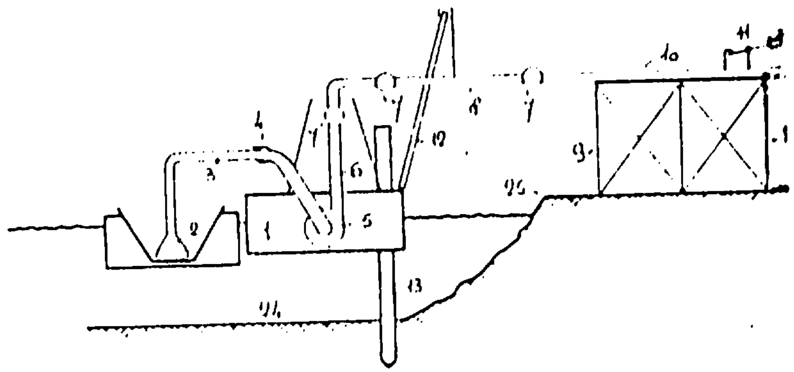
p = port

s = starboard

FIG. V-10.1

Fig. V. 11.1.





BARGE UNLOADING

RECLAMATION DREDGER

general layout

V-II BARGE UNLOADING DREDGER (RECLAMATION DREDGER) (REHANDLER (Am.))

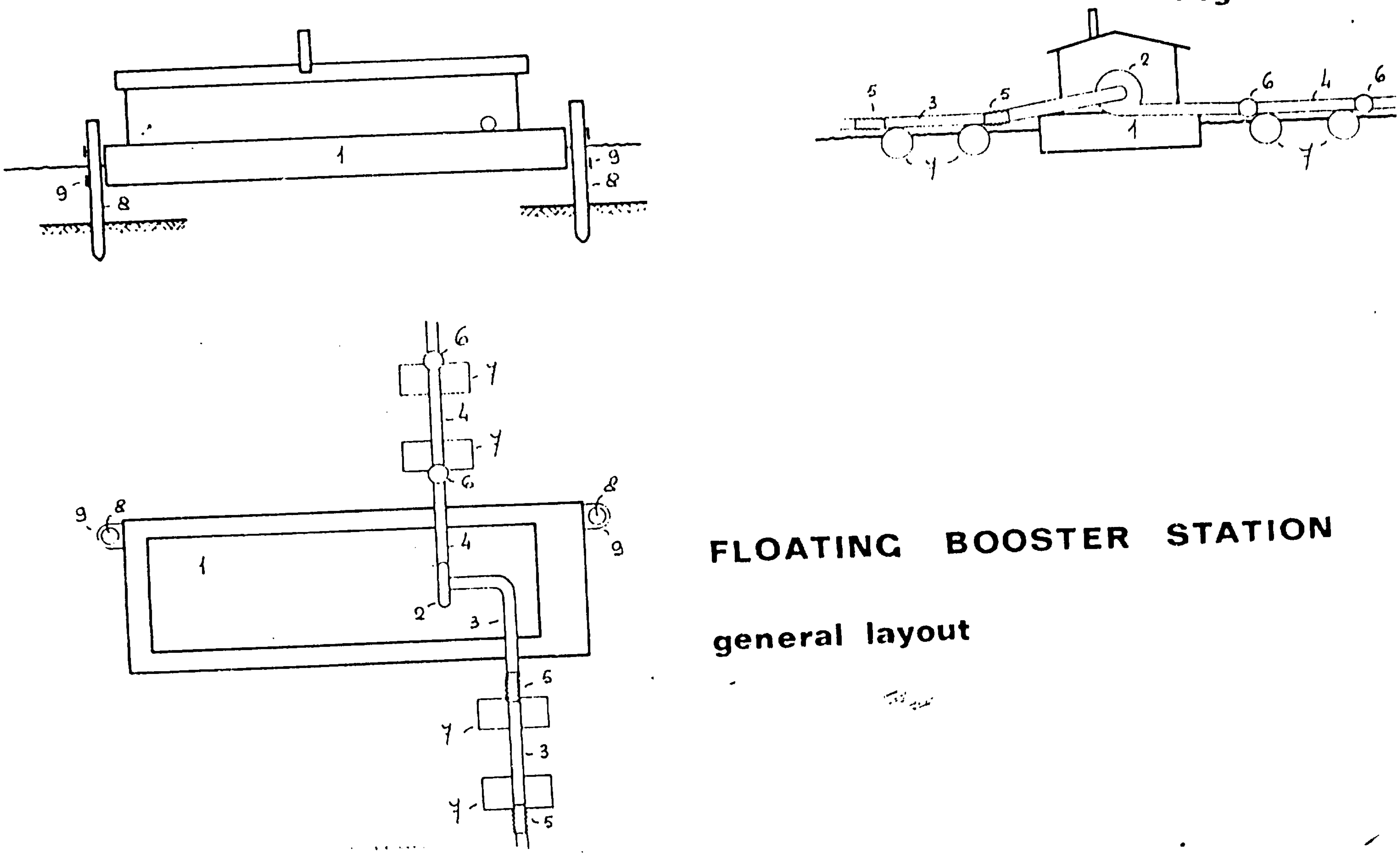
fig. V-II.I General plan - elevation - cross section

1. Pontoon
2. Suction orifice
3. Suction tube
4. Revolving joint in the suction tube
5. Dredge pump
6. Riser on the dredge pump
7. Ball joint
8. Shore delivery pipe
9. Scaffolding for pipe support
10. Shore pipe line
11. Air inlet to prevent under-pressure
12. Gantry for hoisting the pipe no. 8
13. Anchoring spudpole

13a. Spud keeper

14. Filter for no. 16 (sea chest)
15. Clean water suction pipe
16. Clean water pump
17. Pipe line for no. 16
18. Switch valve system, inter-connected and hydraulically operated
19. Short-cut between nos. 5 and 16 to maintain supply to dredge pump
20. Revolving joint in clean water pipe
21. Pressure hose in hinged section of clean water pipe
22. Jetting nozzle
23. Spoil barge
24. Bottom of the canal
25. Embankment of the canal
26. Boom for suspension suction pipe
27. Suction pipe hoist
28. Suction pipe wire
29. Barge shifting winch
30. Barge shifting winch
31. Bollards for mooring and shifting

Fig. V. 12. 1.



FLOATING BOOSTER STATION

general layout

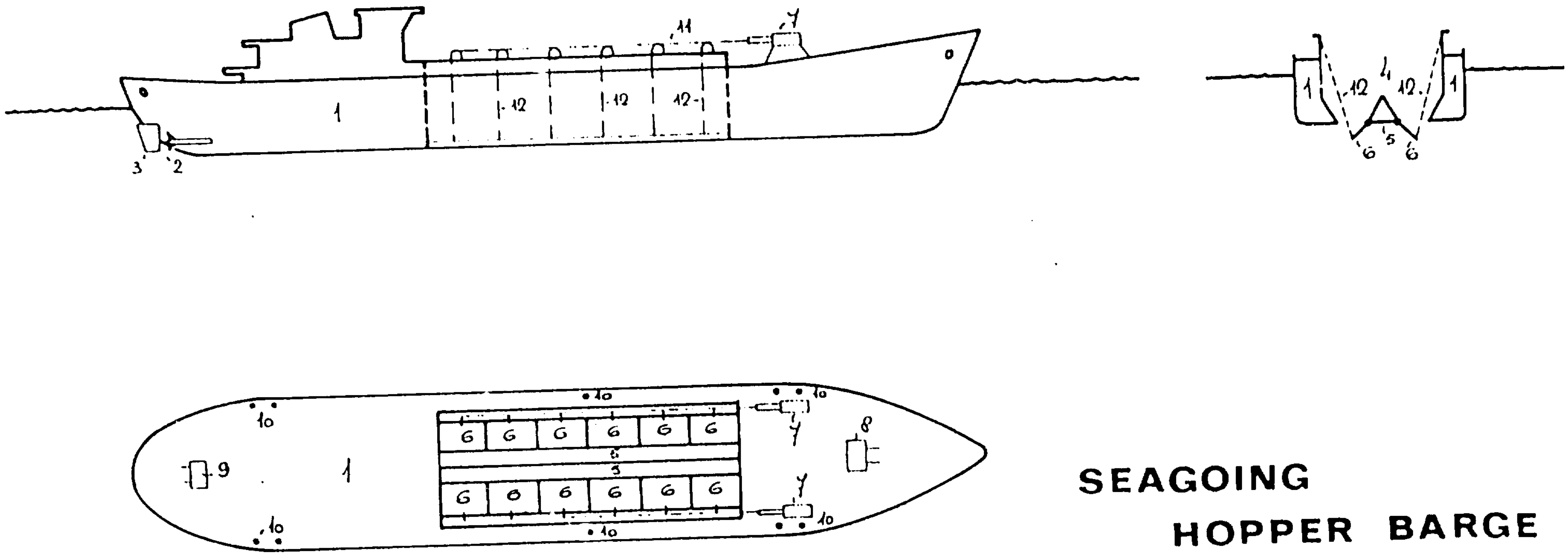
V-12 FLOATING BOOSTER STATION

fig. V-12.1 General lay-out

1. Pontoon
2. Booster dredge pump
3. Connection of floating pipe line - suction side
4. Connection of floating pipe line - discharge side
5. Suction hose connection (instead of balljoint to prevent possible air leakage)
6. Ball joint connection
7. Floats for the pipeline
8. Spud poles for anchorage
9. Spud keeper

FIG V-12.1

Fig. V. 13. 1.



SEAGOING HOPPER BARGE

general layout

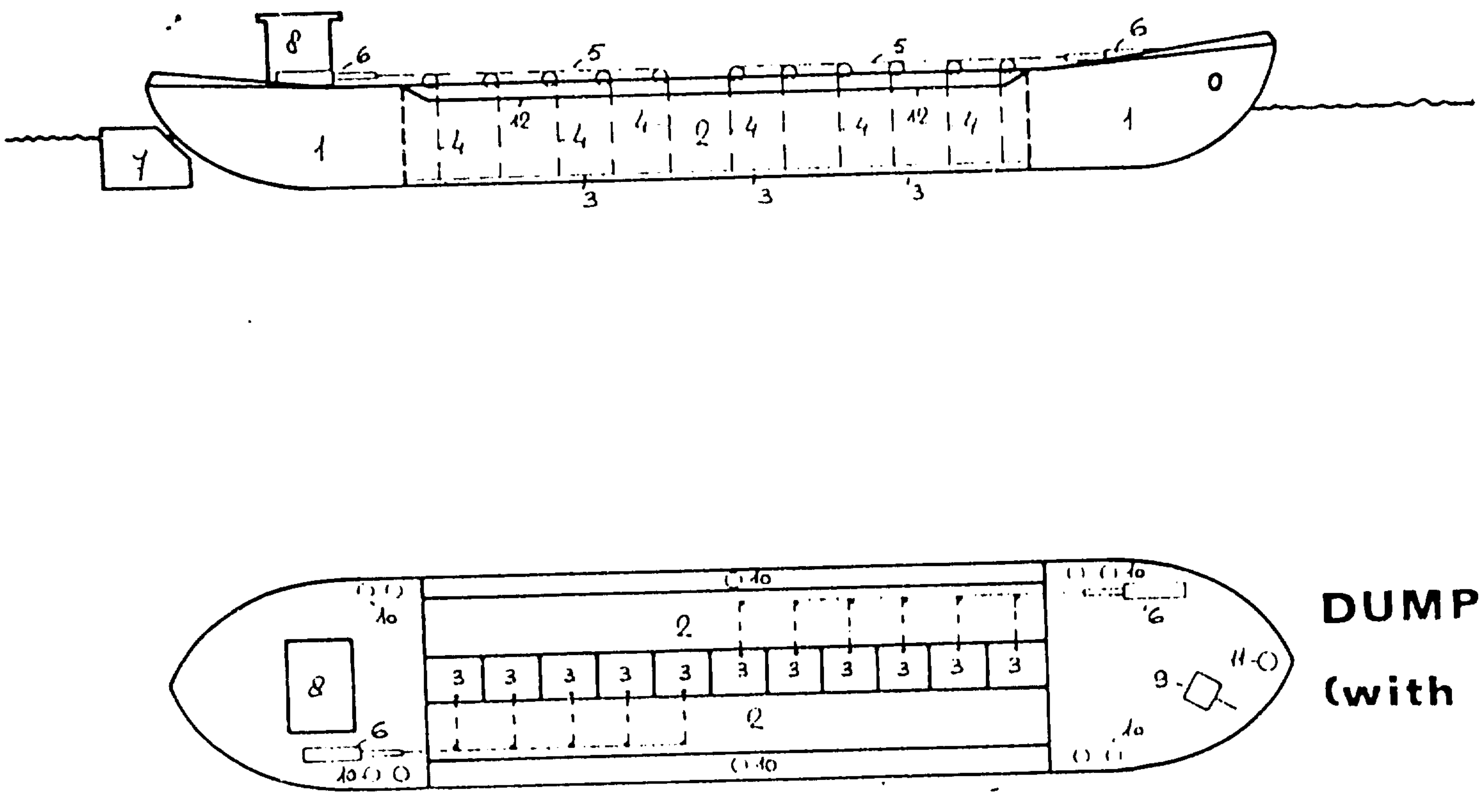
V - 13 SEAGOING HOPPER BARGE

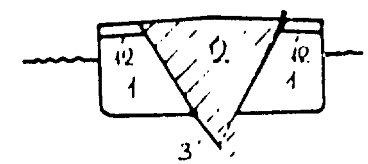
fig. V - 13.1 General lay-out

1. Ship
2. Propeller
3. Rudder
4. Hopper
5. Center keelson
6. Hopper doors
7. Hydraulic rams for door suspension
8. Forward windlass
9. Stern windlass
10. Ballards for mooring
11. Horizontal door hoisting bars, connected to no 7
12. Door chains, connected to no 11

FIG. V - 13.1

Fig. V. 14. 1.





DUMP BARGE

(with bottom discharge door

general layout

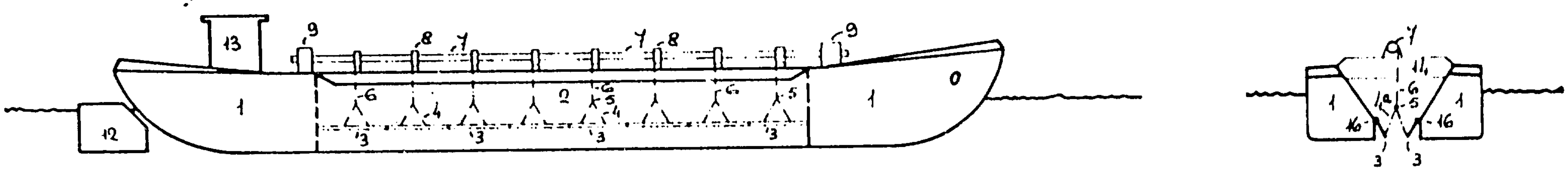
V-14 DUMP BARGE WITH BOTTOM DISCHARGE DOORS

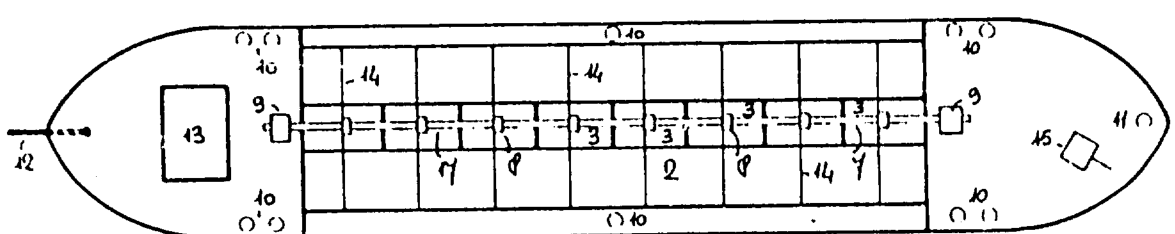
fig. V-14.1 General lay-out

1. Ship
2. Hopper
3. Hopper doors
4. Chains for door suspension
5. Horizontal door hoisting bar, connected to no 6
6. Hydraulic ram
7. Rudder
8. Cabin
9. Anchor winch
10. Bollards
11. Towing bollard
12. Deck of gangway (forward and aft decks are raised)

FIG. V-14.1

Fig. V. 15.1.





DUMP BARGE
(with raised bottom discharge doors)
general layout

V - 16 DUMP BARGE WITH RAISED HOPPER DOORS

fig. V-15.1 General plan

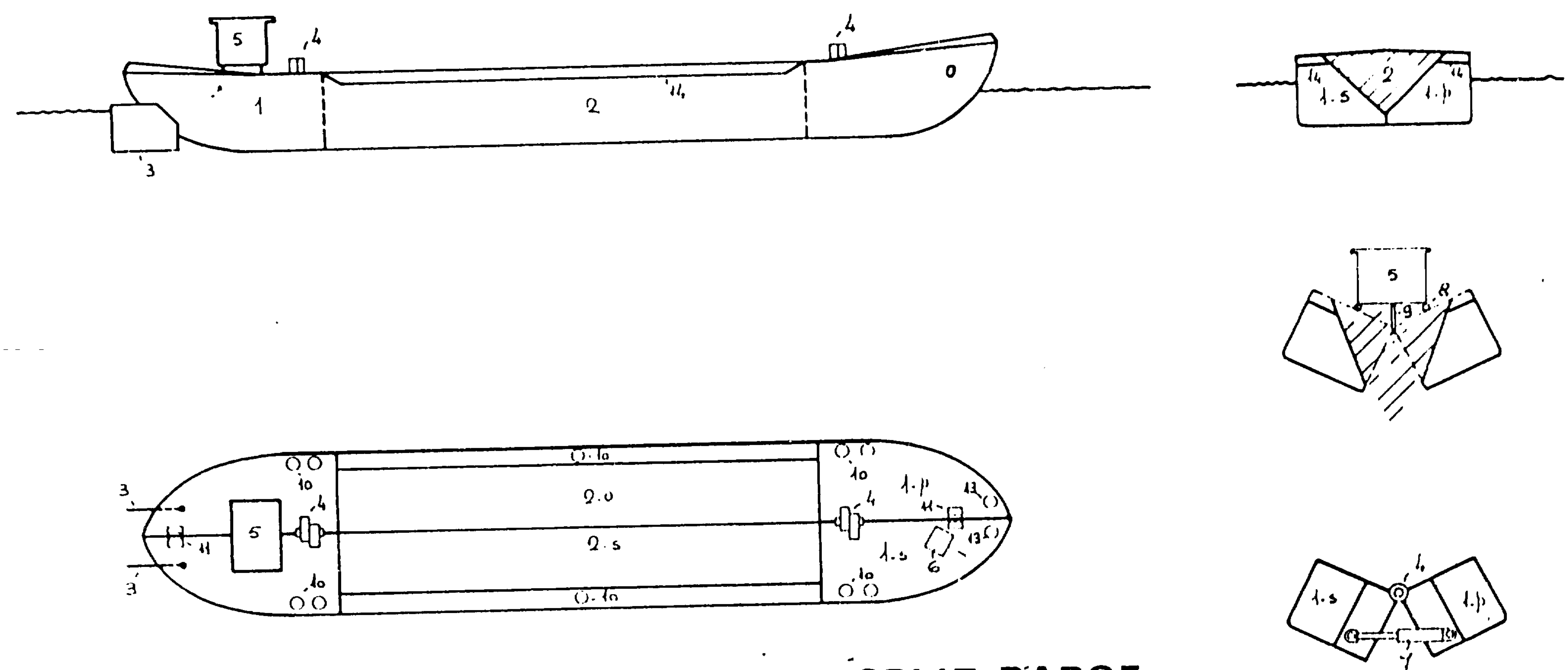
1. Ship
2. Hopper
3. Hopper doors
4. Door chains

4a. Bridle chain for suspension of d uble doors

5. Balancer
6. Main chain
7. Winding shaft for main chains
8. Bearings for no. 7
9. Gear wheels for driving the winding shaft
10. Bollards
11. Towing bollard
12. Rudder
13. Cabin
14. Cross beams suspending the winding shaft
15. Anchor winch
16. Raised hinges for the doors; opened doors do not project below the ship

FIG. V-15.1

Fig. V.16.1.



SPLIT BARGE

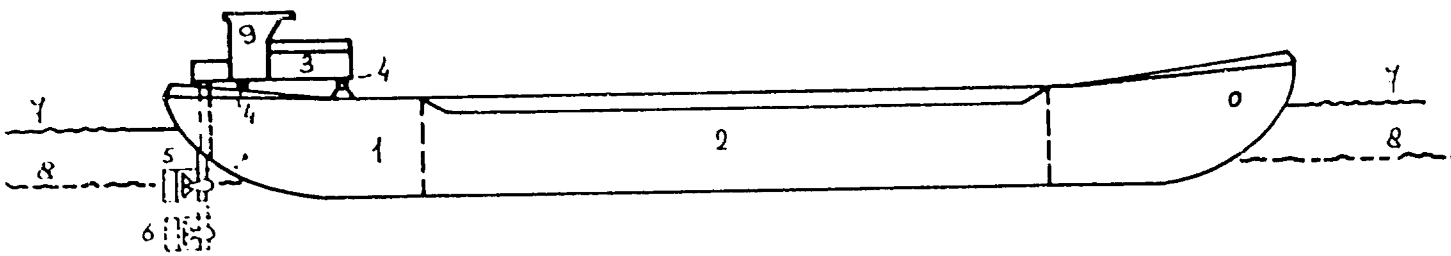
general layout

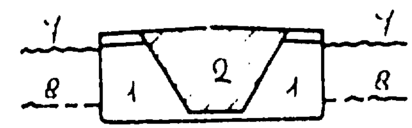
V - 16 SPLIT BARGE

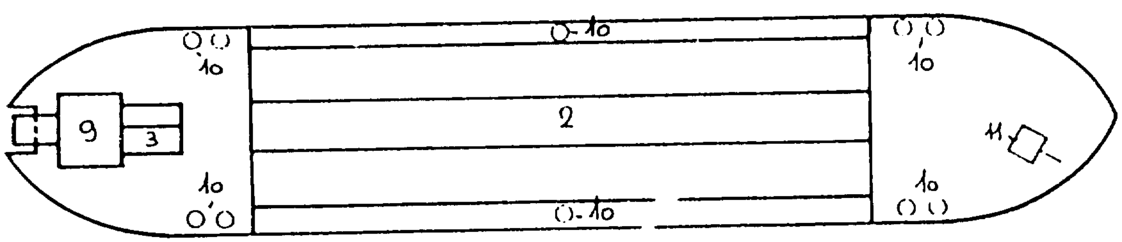
fig V-16.1 General lay-out

1 Ship
2 Hopper
3 Rudder
4 Hinges (connecting both ship-halves)
5 Cabin (bridge)
6 Anchor winch
7 Hydraulic ram for closing and opening the two ship halves
8 Support of the bridge on rollers
9 Vertical guide for the bridge
10 Bollards
11 Additional support for reducing the amidships bending moments in the ship-halves in the horizontal plane
12 Compartment for hydraulic ram
13 Towing bollard
14. Deck of gangway (forward and aft decks are raised)

Fig. V. 17. I.







SELF PROPELLED BARGE

for use with barge unloading dredger or an elevator. (shown with 'Schottel' propulsion unit)

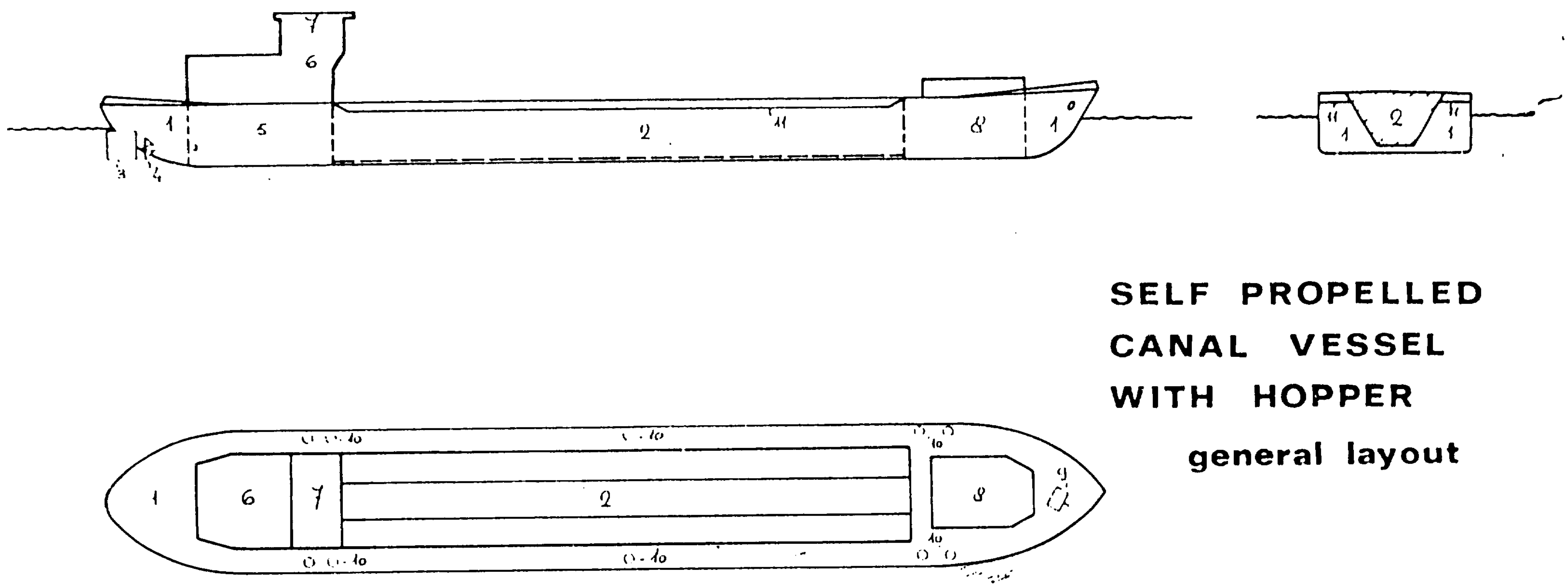
V-17 SELF PROPELLED BARGE WITH SCHOTTEL NAVIGATOR

fig. V-17.1 General lay-out

1. Ship
2. Hopper
3. Self contained motor unit
4. Three-point foundation to the deck
5. Position of the propeller, when fully loaded
6. Position of the propeller, when empty
7 Water surface - loaded
8 Water surface - empty
9. Cabin (bridge); united to no. 3
10. Bollards
11. Anchor winch

FIG. V-17.1

Fig. V. 18.I.



SELF PROPELLED CANAL VESSEL WITH HOPPER

general layout

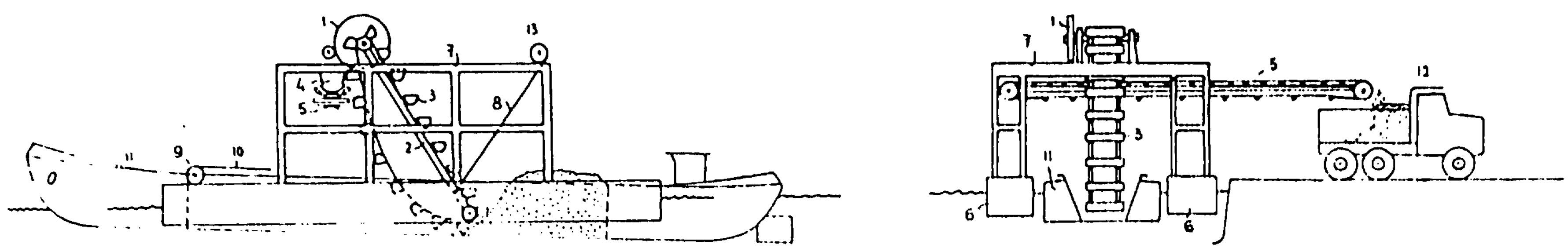
V-18 SELF PROPELLED CANAL BARGE WITH LIVING QUARTERS

fig V-18 1 General lay-out

1 Ship
2 Hopper
3 Rudder
4 Propeller
5. Engine room
6 Living quarters captain's family
7 Bridge
8 Deckhand s family quarters
9 Anchor winch
10 Bollards
11 Deck of gangway (forward and aft decks are raised)

FIG. V-18.1

FIG. V. 19. 1.



ELEVATOR

general layout

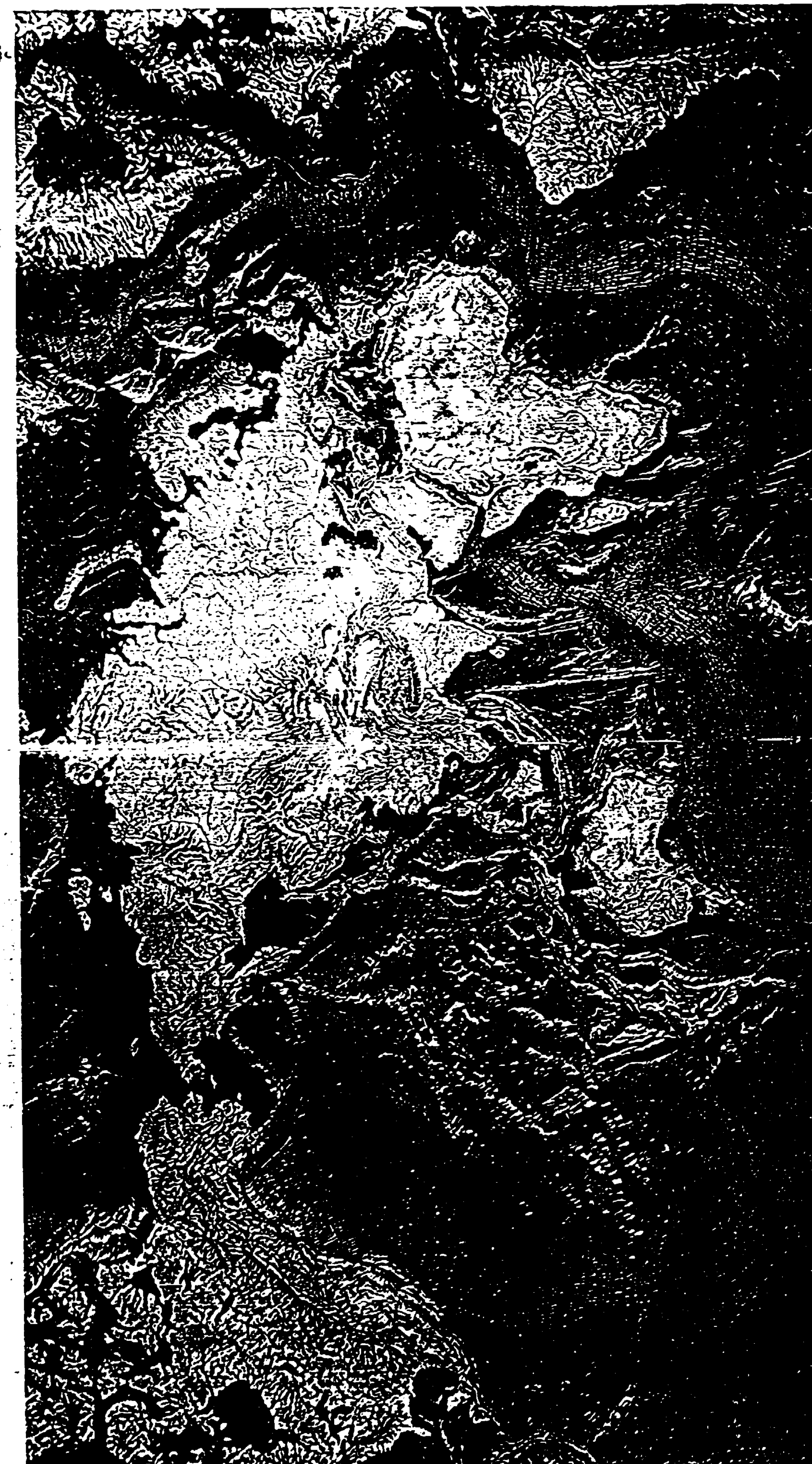
V-19 ELEVATOR

fig. V-19.1 General lay-out

1. Main driving wheel
2. Ladder
3. Elevator buckets
4. Receiving hopper
5. Belt conveyor
6. Twin hulls
7. Super structure
8. Ladder hoist wire
9. Winch for shifting barges
10. Shifting wire
11. Barge of the elevator type
12. Sand truck
13. Ladder hoisting winch

FIG. V-19.1

Professor Adalberto Vallega
University of Genova



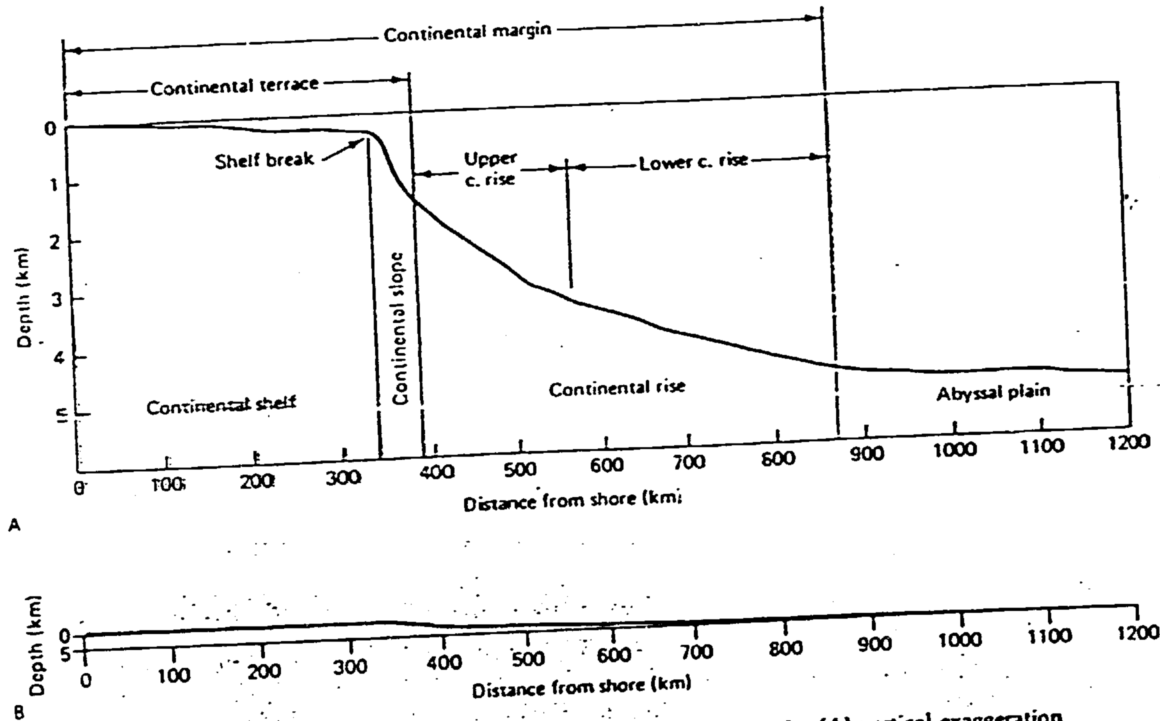


Figure 2-7. Principal features of the Atlantic continental margin. (A) vertical exaggeration 1/50; (B) no vertical exaggeration (Based on B. Heezen and others, 1959, and B. Heezen, 1962; after W. A. Anikouchine and R. W. Sternberg, 1973)

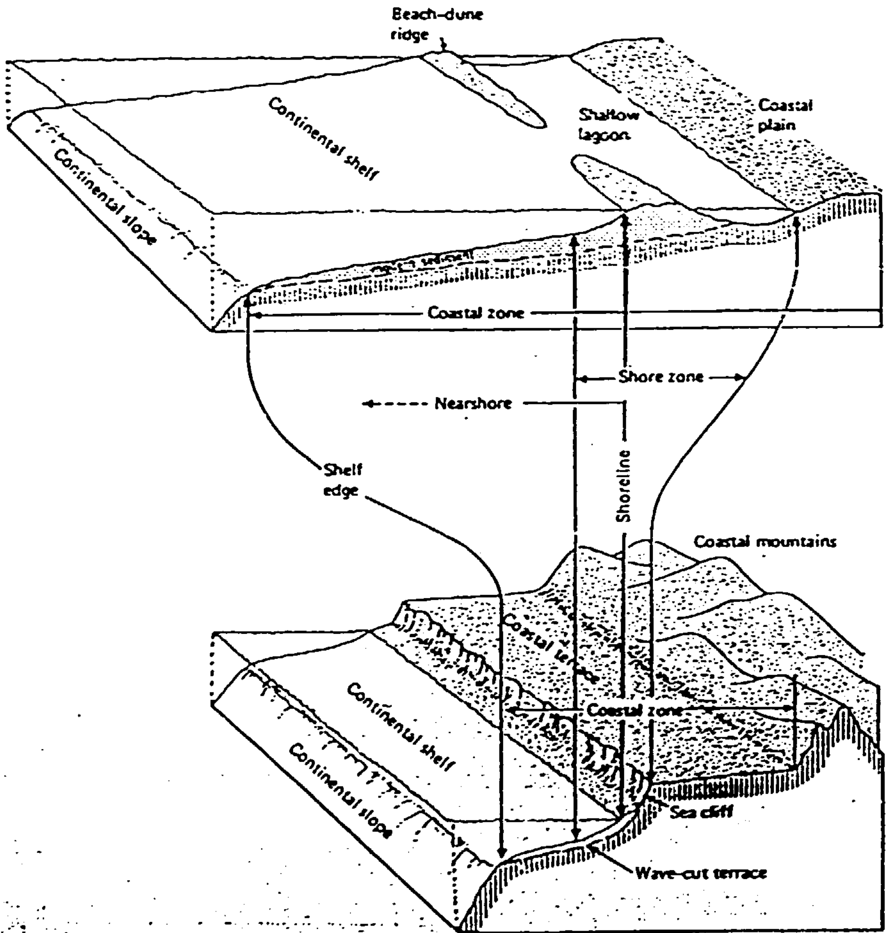


Figure 9-1 General coastal zone characteristics for trailing edge margins (top) and collision edge margins (bottom). Note the wide shelf plains coast of trailing edge margins and narrow shelf mountainous coast of collision edge margins. (From D. L. Inman and B. M. Brush, 1973)

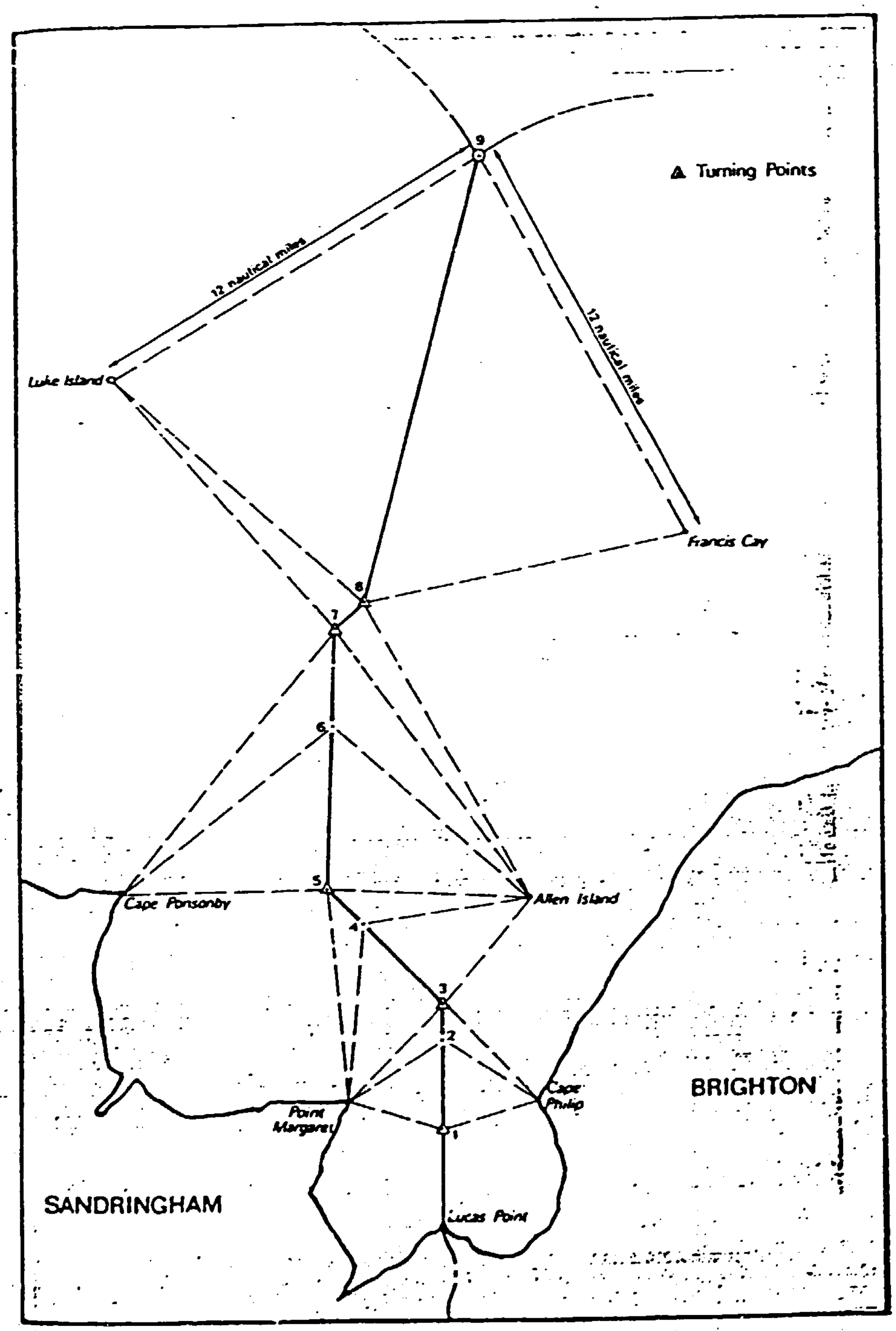


Figure 4.2 The construction of a line of equidistance

	CONTINENTAL SHELF
NAVIGATION	Aliens have full navigation rights providing that they observe safety zones designated by the coastal state around artificial islands, installations and structures (50).
OVERFLIGHT	Aliens have full overflight rights.
FISHING	Aliens have rights to fish in the water column; they are prohibited from catching sedentary species (77.4 and 78).
SCIENTIFIC RESEARCH	Research can be conducted in the water column, but consent of the coastal state would be required for research on the seabed (246 and 257).
LAYING SUBMARINE CABLES	Aliens possess rights (79).
MINING	Aliens have no rights.
IMPOSITION OF ENVIRONMENTAL LEGISLATION	The coastal state has complete authority to legislate for the protection of the seabed environment (194.2 and 200) providing such regulations do not unjustifiably interfere with the rights and duties of aliens (194.4). Aliens have rights to conduct scientific research in those areas of the shelf, more than 200 nm from the baseline, which have not been designated by the coastal state as areas within which exploration or exploitation will occur in a reasonable time (246.6). Warships are exempt because they possess sovereign immunity (236).

Figure 5.2 High seas in the Arctic Ocean

JURISDICTIONAL FRAMEWORK

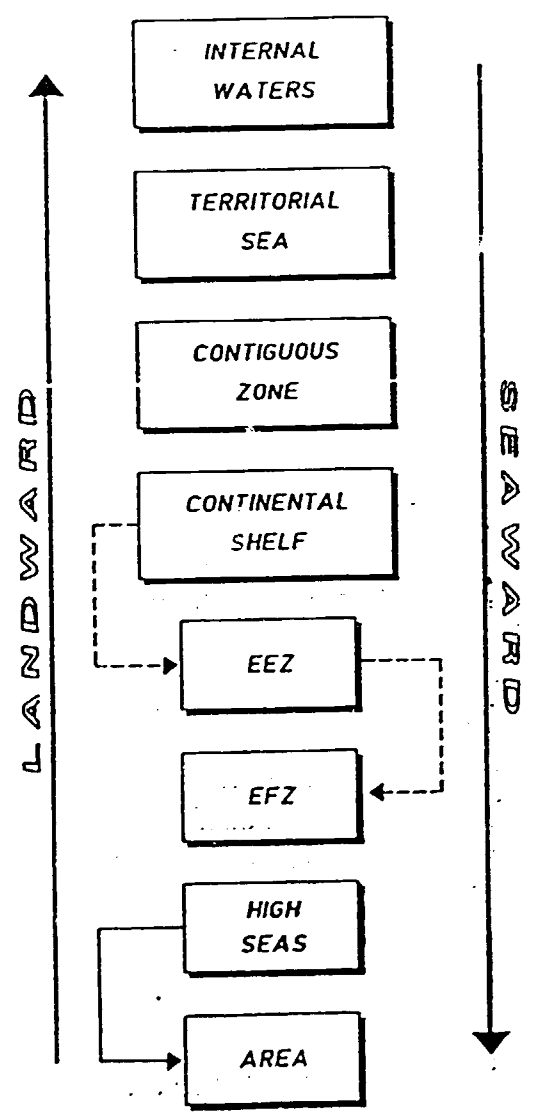


Figure 3 *Marine jurisdictional belts.*

A. VALLEGA
DESIGN: G. [illegible] P. [illegible]

	CONTIGUOUS ZONE
NAVIGATION	Aliens have full navigation rights providing they have not infringed regulations relating to the territorial sea (33).
OVERFLIGHT	Aliens have full overflight rights.
FISHING	Aliens would possess rights to fish if no fishing zone or exclusive economic zone had been proclaimed extending beyond the seaward limit of the territorial sea. Sedentary species could not be caught (77.4).
SCIENTIFIC RESEARCH	Aliens would possess rights to conduct research in the water column if no fishing zone or exclusive economic zone had been proclaimed extending beyond the seaward limit of the territorial sea. However, no research could be conducted on any continental shelf underlying the contiguous zone in this situation (246).
LAYING SUBMARINE CABLES	Aliens possess rights.
MINING	Aliens have no rights
IMPOSITION OF ENVIRONMENTAL LEGISLATION	The coastal state would have authority only if the contiguous zone was overlapped by an exclusive economic zone or underlain by the continental shelf. In the first case the state would have authority over the seabed and the water column; in the second case the state could only legislate for the seabed. Such regulations would have to be consistent with rights of aliens in this zone. Warships are exempt because they possess sovereign immunity (236).

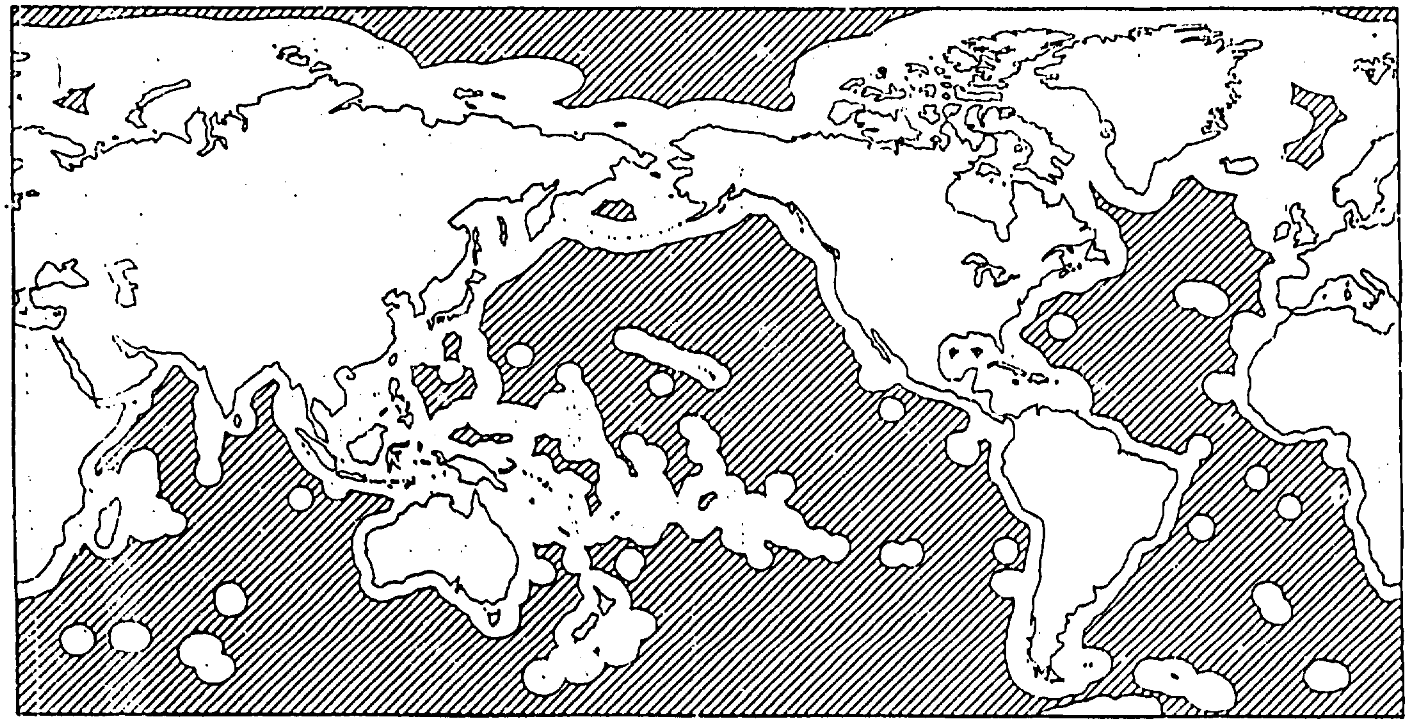


Figure 5.1 The high seas

	EXCLUSIVE ECONOMIC ZONE
NAVIGATION	Aliens have full navigation rights providing they observe safety zones designated by the coastal state around artificial islands, installations and structures (58 and 60.6).
OVERFLIGHT	Aliens have full overflight rights.
FISHING	Aliens may have access to the surplus allowable catch, determined by the coastal state, through agreements or other arrangements with the coastal state, which shall take into account the need to minimize economic dislocation to aliens who have habitually fished these waters (62). Under certain circumstances, aliens of landlocked states and of states with special geographical characteristics have the right to participate on an equitable basis, in the exploitation of an appropriate part of the surplus living resources in the EEZ of near-by coastal states (69 and 70).
SCIENTIFIC RESEARCH	Research can only be conducted with the consent of the coastal state (246).
LAYING SUBMARINE CABLES	Aliens possess rights (58).
MINING	Aliens have no rights.
IMPOSITION OF ENVIRONMENTAL LEGISLATION	The coastal state has complete authority (56.b.iii), providing the rights of aliens are not adversely affected (52.2). Regulations dealing with pollution from vessels should give effect to generally accepted international rules and standards (211.5). Provision exists for imposing special regulations dealing with pollution from vessels after consultation with the competent international authority (211.6). Warships are exempt because they possess sovereign immunity (236).

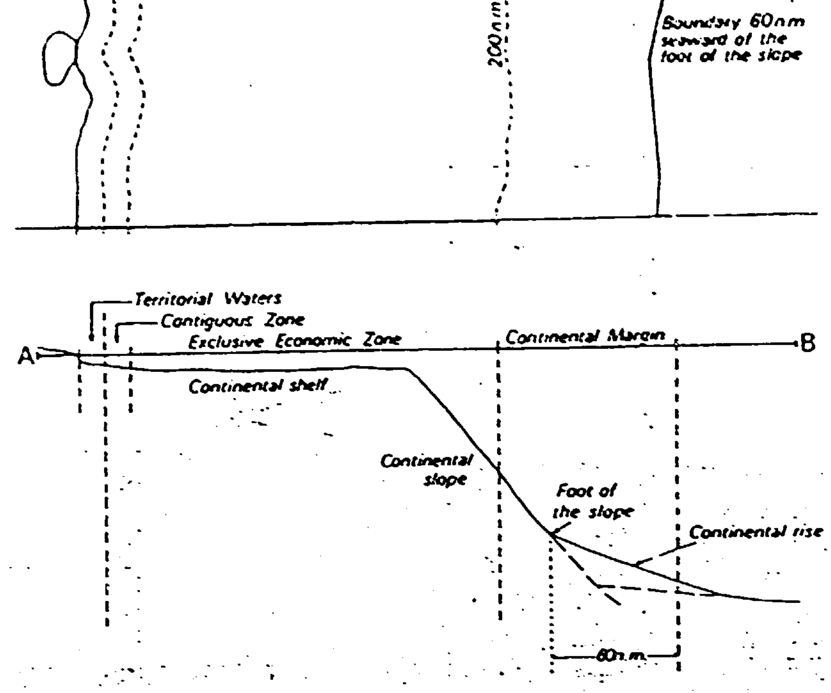


Figure 3.1 . The plan and profile of national maritime claims

intangibles

an example : air pollution

emission

↓

air quality

↓

damage in physical units

↓

monetary damage

Aliens have full overflight rights.	Aliens have full overflight rights.	Aliens have overflight rights, although they might be restricted to designated corridors (53).	[illegible] (87.b).
Aliens may have access to the surplus allowable catch, determined by the coastal state, through agreements or other arrangements with the coastal state, which shall take into account the need to minimize economic dislocation to aliens who have habitually fished these waters (62). Under certain circumstances, aliens of landlocked states and of states with special geographical characteristics have the right to participate on an equitable basis, in the exploitation of an appropriate part of the surplus living resources in the EEZ of near-by coastal states (69 and 70).	Aliens have rights to fish in the water column; they are prohibited from catching sedentary species (77.4 and 78).	Aliens have traditional or agreed rights in waters prior to them being declared archipelagic waters and shall have these rights respected through the concluding of bilateral treaties (51).	All operators have equal rights and obligations (87 e and 116–120).
Research can only be conducted with the consent of the coastal state (246).	Research can be conducted in the water column, but consent of the coastal state would be required for research on the seabed (246 and 257).	Research can only be conducted with the consent of the archipelagic state (54 and 40).	All operators have equal rights, although these do not include the continental shelf which underlies high seas (87.f and 257).
Aliens possess rights (58).	Aliens possess rights (79).	Existing cables shall be respected and may be maintained (51).	All operators have equal rights (87.c).
Aliens have no rights.	Aliens have no rights.	Aliens have no rights.	All operators have equal rights (141).
The coastal state has complete authority (56.b.iii), providing the rights of aliens are not adversely affected (52.2). Regulations dealing with pollution from vessels should give effect to generally accepted international rules and standards (211.5). Provision exists for imposing special regulations dealing with pollution from vessels after consultation with the competent international authority (211.6). Warships are exempt because they possess sovereign immunity (236).	The coastal state has complete authority to legislate for the protection of the seabed environment (194.2 and 200) providing such regulations do not unjustifiably interfere with the rights and duties of aliens (194.4). Aliens have rights to conduct scientific research in those areas of the shelf, more than 200 nm from the baseline, which have not been designated by the coastal state as areas within which exploration or exploitation will occur in a reasonable time (246.6). Warships are exempt because they possess sovereign immunity (236).	Archipelagic states have complete authority to legislate for protection of the environment in these waters (50 and 42), and are bound not to use regulations to hamper innocent passage (50, 42.2 and 44). Warships are exempt because they possess sovereign immunity (236).	All operators have equal responsibilities (116–120).

cost - effectiveness

objective → constraint

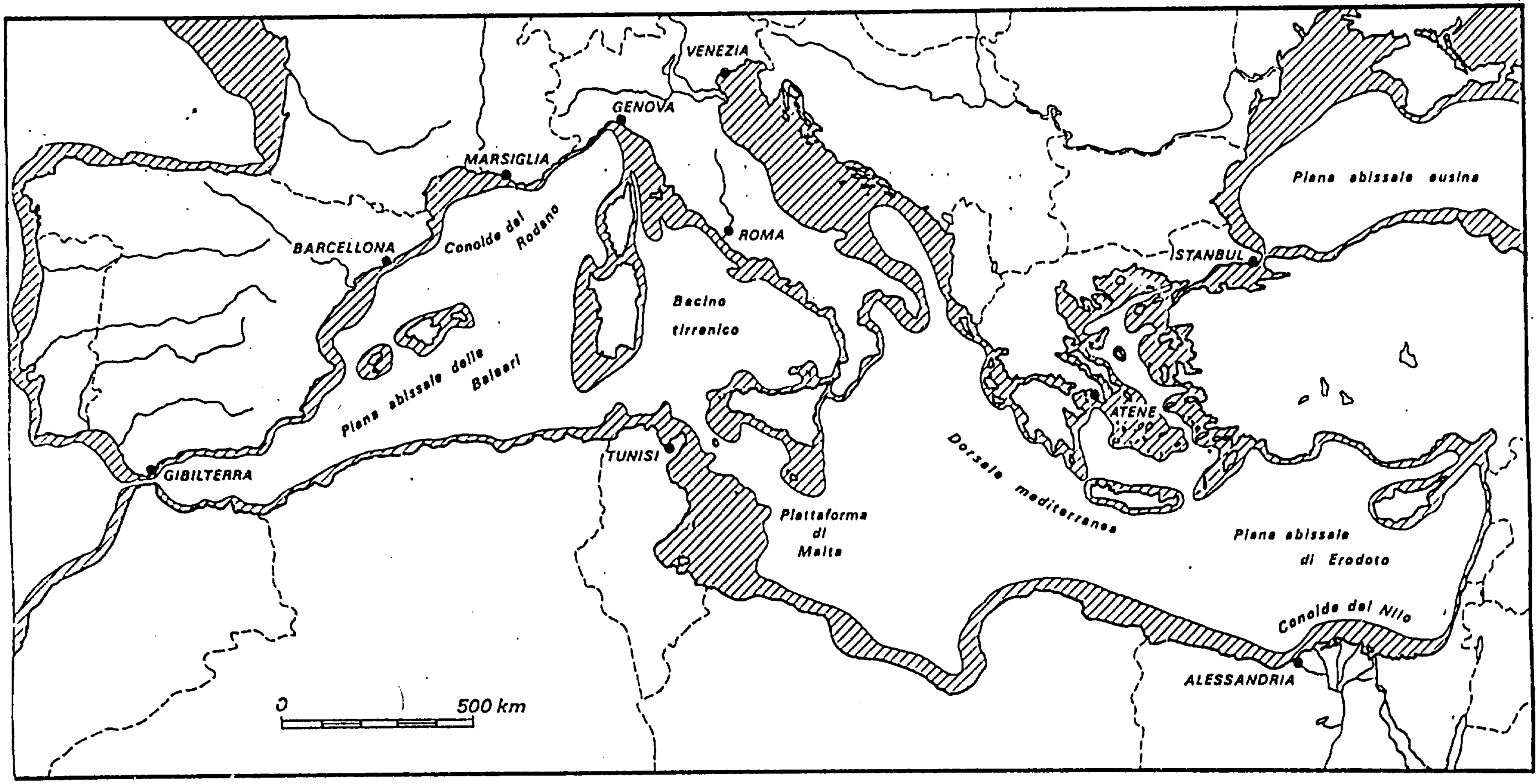
an example

$$\min C(w)$$
$$P(z, w) = 0$$
$$Q(z) \geq Q^*$$

Q^* environmental (or emission) standard

who (and how) sets Q^* ?

suboptimal strategy

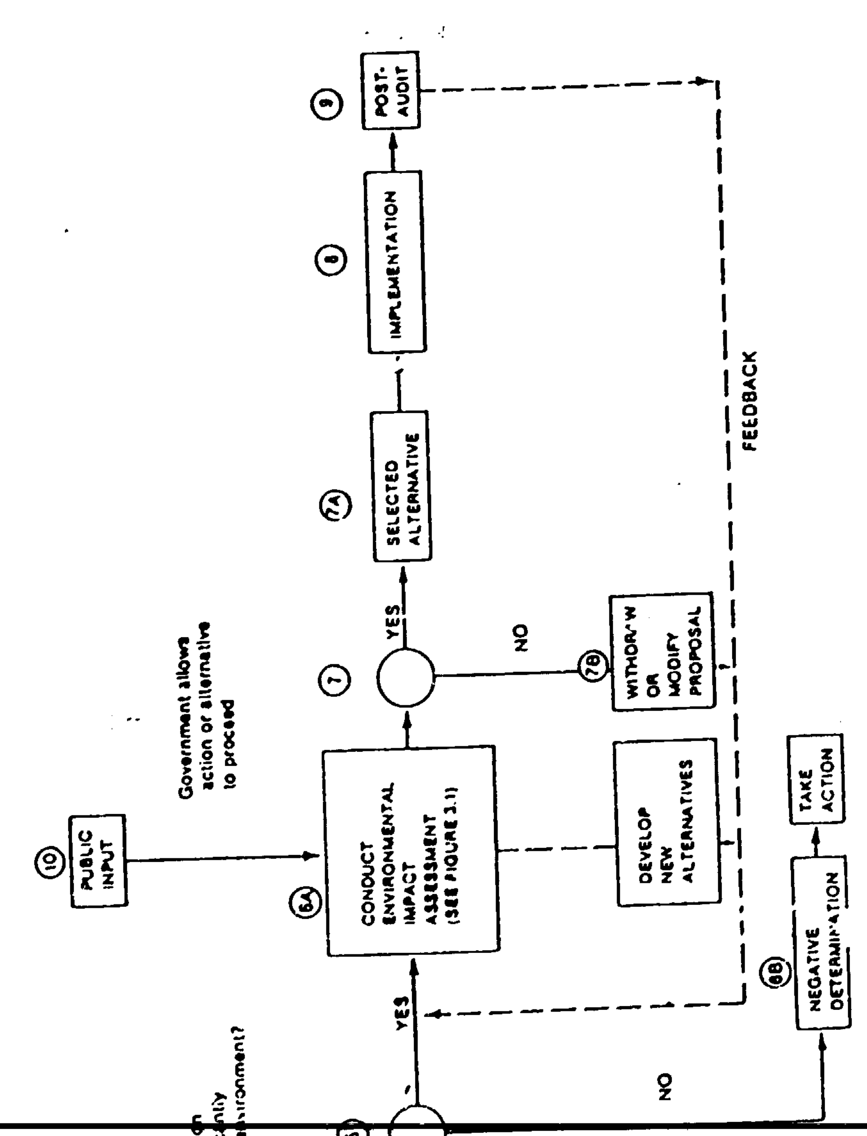


VENEZIA
GENOVA
MARSIGLIA
BARCELLONA
Conoide del Rodano
ROMA
Piana abissale eusina
STANBUL
Bacino tirrenico
Piana abissale delle Baleari
ATENE
TUNISI
GIBILTERRA
Dorsale mediterranea
Piattaforma di Malta
Piana abissale di Erodoto
Conoide del Nilo
ALESSANDRIA
0
500 km

ARCHIPELAGIC WATERS

NAVIGATION	Aliens have the right of innocent passage though the archipelagic state may designate sea lanes for continuous and expeditious passage, and may close certain areas temporarily for the protection of its security (52 and 53). Where archipelagic waters intrude between two parts of a neighbouring state existing traditional rights and interests will be preserved (47.7).
OVERFLIGHT	Aliens have overflight rights, although they might be restricted to designated corridors (53).
FISHING	Aliens have traditional or agreed rights in waters prior to them being declared archipelagic waters and shall have those rights respected through the concluding of bilateral treaties (51).
SCIENTIFIC RESEARCH	Research can only be conducted with the consent of the archipelagic state (54 and 40).
LAYING SUBMARINE CABLES	Existing cables shall be respected and may be maintained (51).
MINING	Aliens have no rights.
IMPOSITION OF ENVIRONMENTAL LEGISLATION	Archipelagic states have complete authority to legislate for protection of the environment in these waters (50 and 42), and are bound not to use regulations to hamper innocent passage (50, 42.2 and 44). Warships are exempt because they possess sovereign immunity (236).

OVERFLIGHT	All operators have equal rights (87.b).
FISHING	All operators have equal rights and obligations (87.c and 116–120).
SCIENTIFIC RESEARCH	All operators have equal rights, although these do not include the continental shelf which underlies high seas (87.f and 257).
LAYING SUBMARINE CABLES	All operators have equal rights (87.c).
MINING	All operators have equal rights (141).
IMPOSITION OF ENVIRONMENTAL LEGISLATION	All operators have equal responsibilities (116–120).



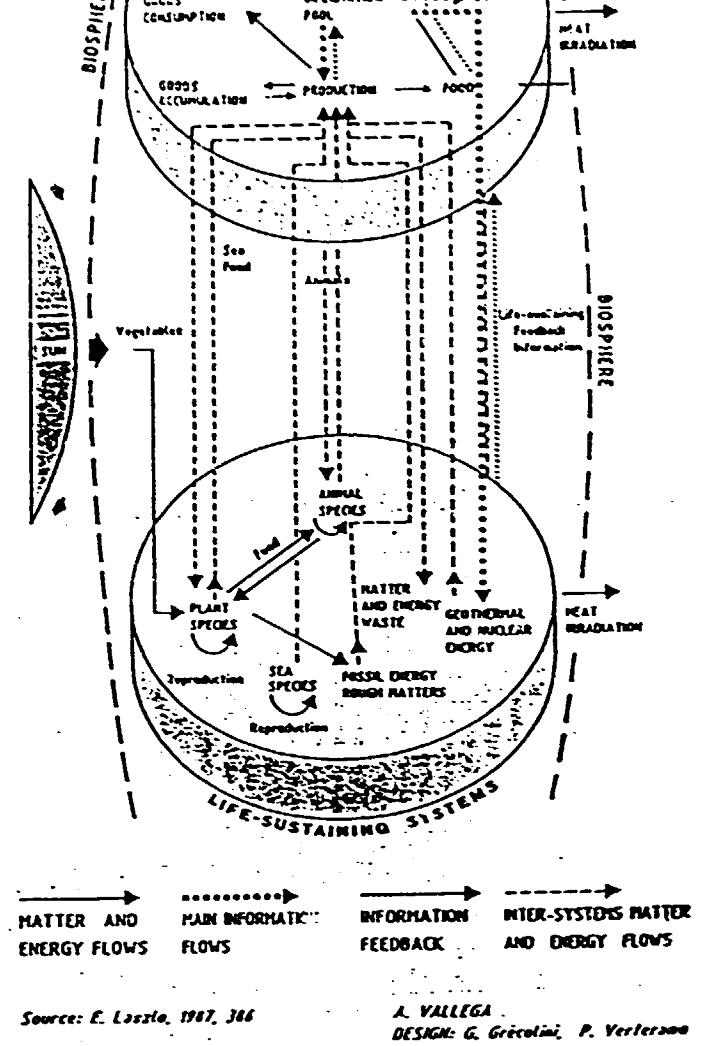
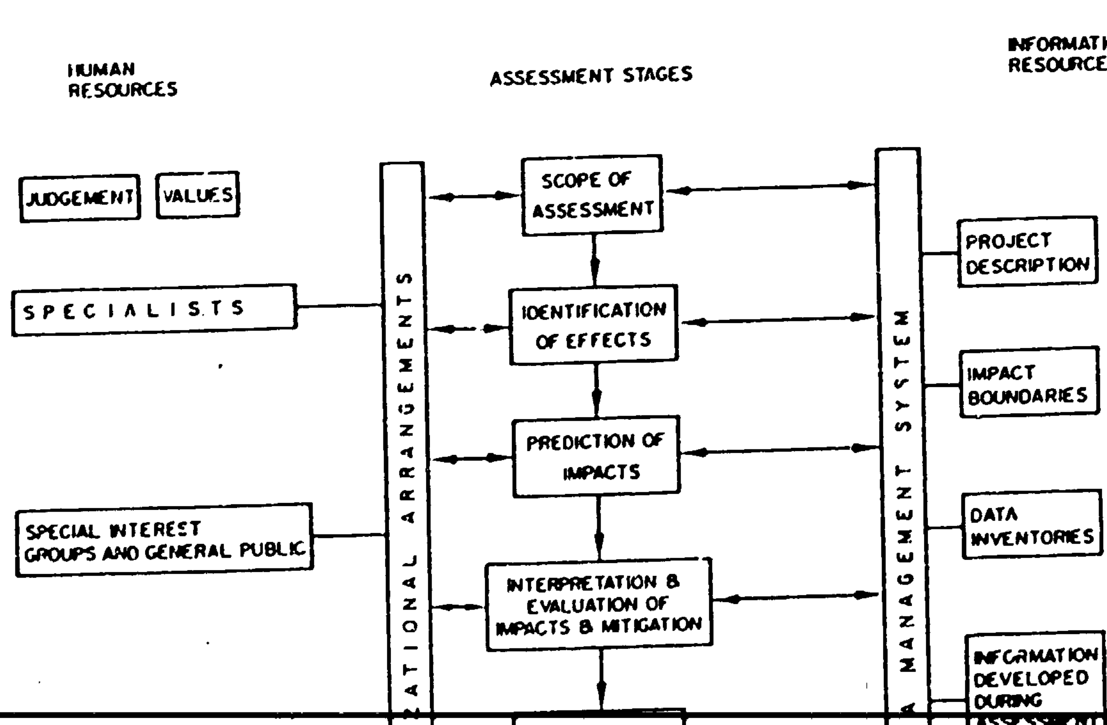


Figure 12 *Interactions between social systems and the ecosystem.*



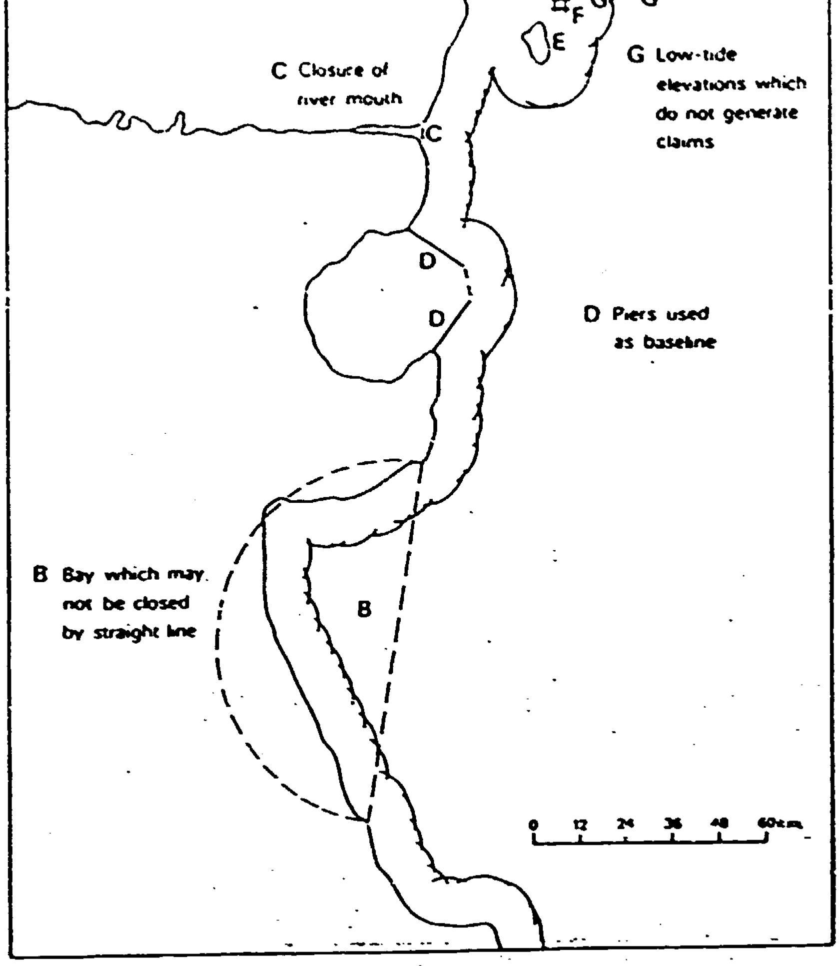
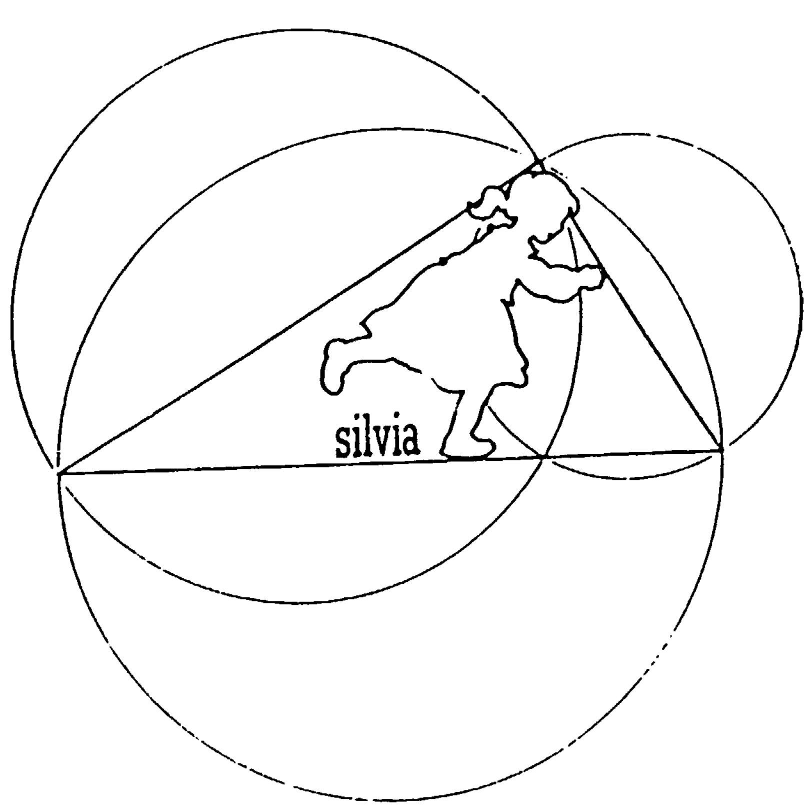


Figure 3.2 Local straight baselines



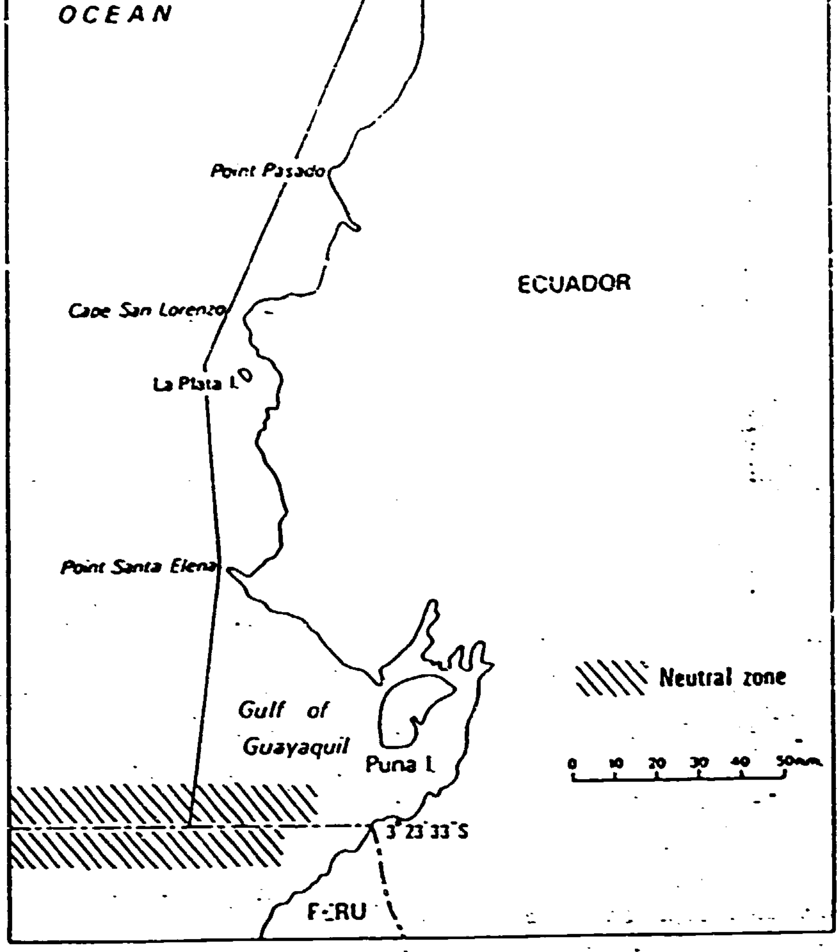


Figure 3.8 Ecuador's straight baselines

SILVIA

- a DSS for Environmental Impact Assessment
- a software guideline (to perform / to review) an EIA study

  - transparency
  - repeatibility
  - participation

(intelligence) (design) (choice)

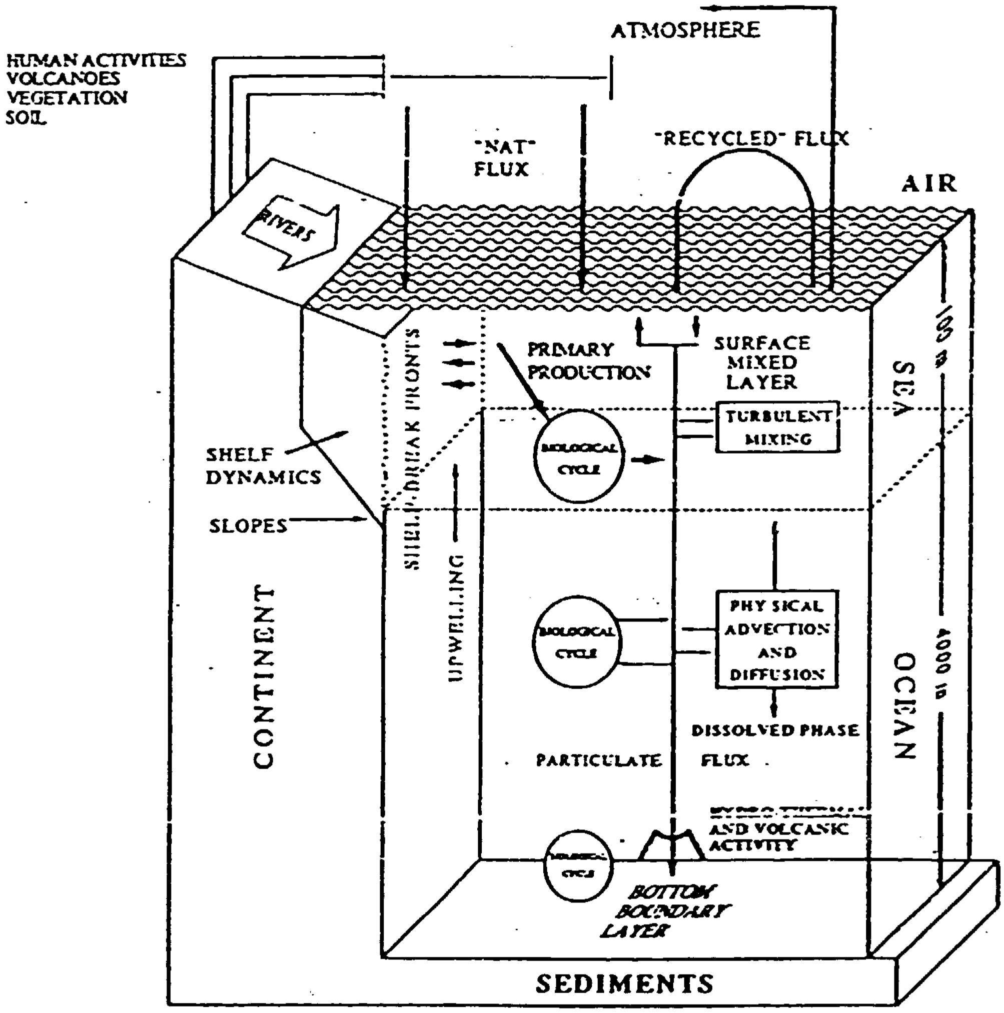


Figure 2.9 *The model of major natural marine processes.* From GESAMP, 1982.

	TERRITORIAL WATERS
NAVIGATION	Aliens have the right of innocent passage providing they comply with legitimate laws and regulations adopted by the coastal state and with accepted international regulations to prevent collisions at sea (21). Aliens have the right of transit passage through straits used for international navigation (35). Aliens must follow designated sea lanes and traffic separation schemes (22 and 41).
OVERFLIGHT	Aliens may overfly straits used for international navigation (38).
FISHING	Aliens have no rights.
SCIENTIFIC RESEARCH	Research can only be conducted with the express consent of the coastal state (245).
LAYING SUBMARINE CABLES	Aliens have no rights.
MINING	Aliens have no rights.
IMPOSITION OF ENVIRONMENTAL LEGISLATION	The coastal state has complete authority (21 d and f), providing it does not hamper innocent passage (211.4). Warships are exempted because they possess sovereign immunity (236).

Professor Elliott Laniado

DECISIONAL PROCESS INVOLVING PUBLIC AUTHORITIES

decisional process involving public authorities

Prof. LANIADO

cost benefit analysis

↓

cost effectiveness analysis

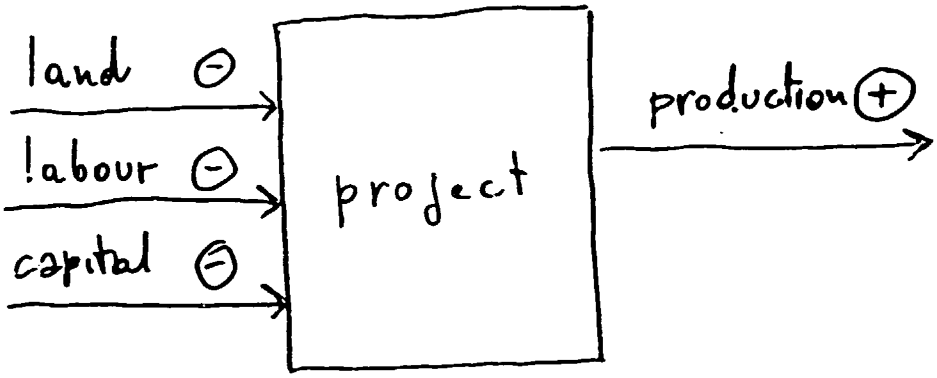
↓

multi criteria analysis

↓

environmental impact assessment
(a decisional procedure)

NOT a cost-benefit analysis

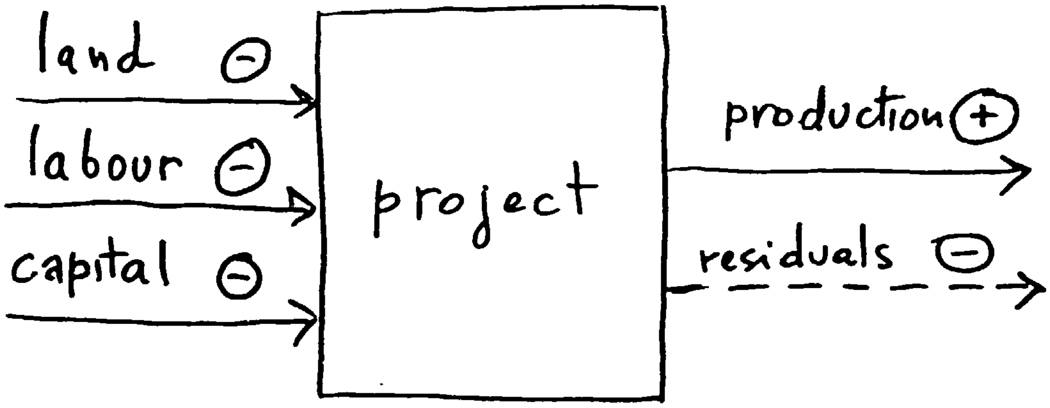


max [RETURNS - COSTS]

↓

- financial (cash-flow) analysis
- market prices

COST - BENEFIT ANALYSIS



max [BENEFITS - COSTS]

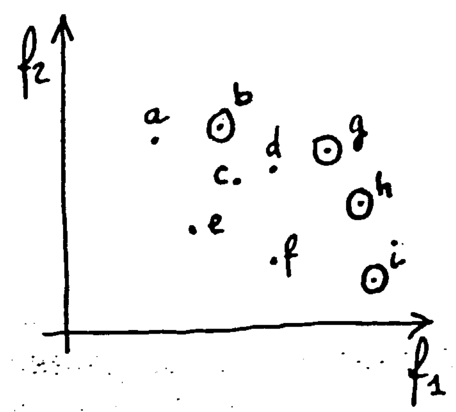
- "real" (social) and not "pecuniary" costs and benefits
- opportunity cost
- a "technical" problem?

multiobjective analysis

The Pareto criterion

$$\max f(x) = \begin{vmatrix} f_1(x) \\ f_2(x) \end{vmatrix}$$

$$x \in X$$



⊙ = efficient (= non dominated) alternatives

d is dominated by g

$$f_1(d) \leq f_1(g)$$

$$f_2(d) \leq f_2(g)$$

↳ alternative d can be eliminated

Environmental Impact Assessment

- project alternatives
- conflicting objectives
- subjective valuation

⇓

participation

⇓

integration of "technical" and "procedural" aspects

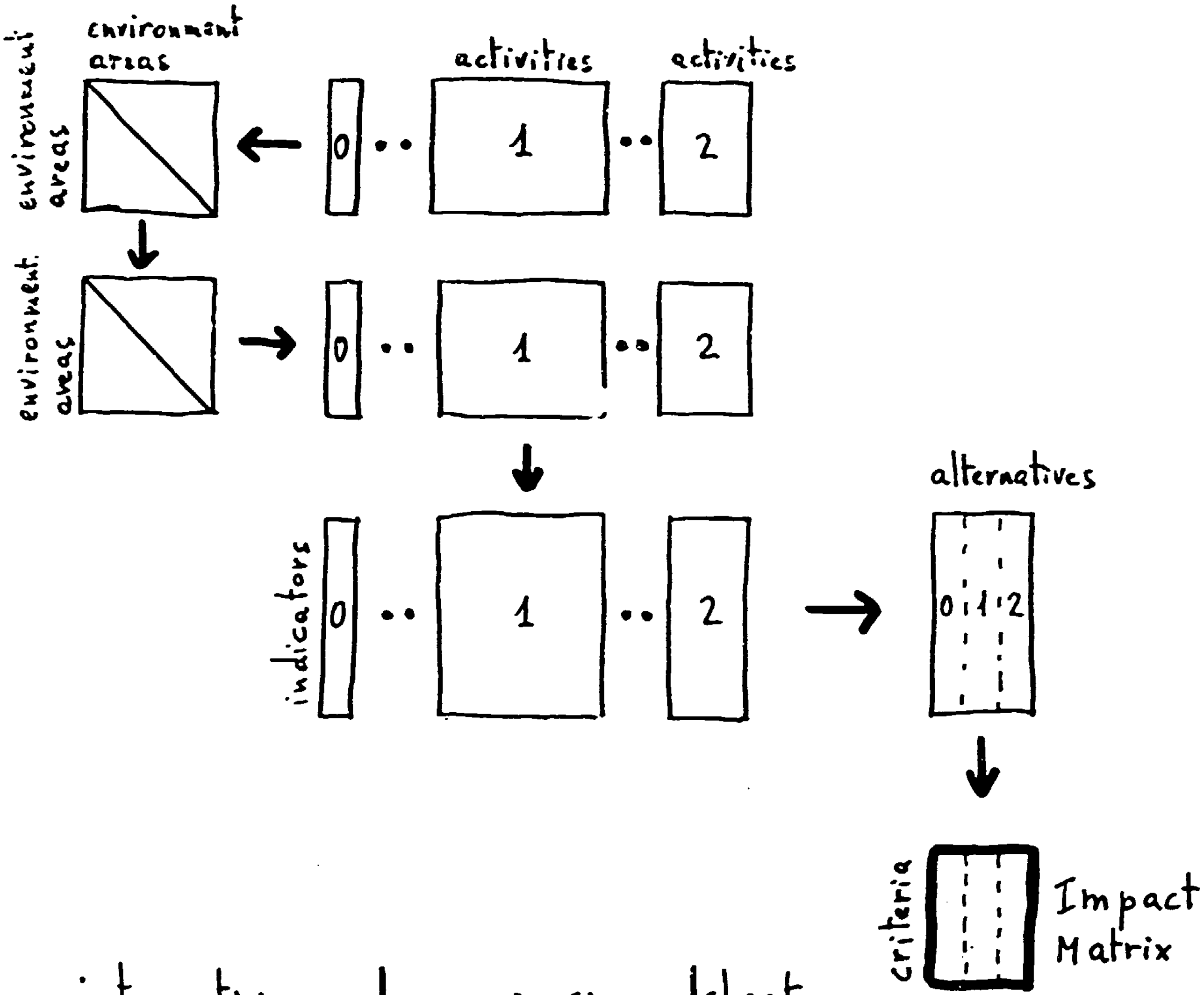
SERENA

- an automatic shelf
- a data-bank containing 7 data-bases
  - legislation
  - checklists
  - matrices
  - information on existing data
  - models
  - case studies
  - bibliography
- search procedure

  any combination (AND/OR)

  of about 150 keywords
  - projects
  - environmental components
  - socioeconomical aspects
  - disciplines
  - attributes

GAIA



interactive code ⇝ spreadsheet

visualization ⇝ matrices

rows and columns ⇝ hierarchic checklists (trees)

system analysis ⇝ networks

initial information ⇝ data

derived information ⇝ models

result ⇝ impact matrix

VISPA

- Features :

  (a) qualitative and quantitative estimates

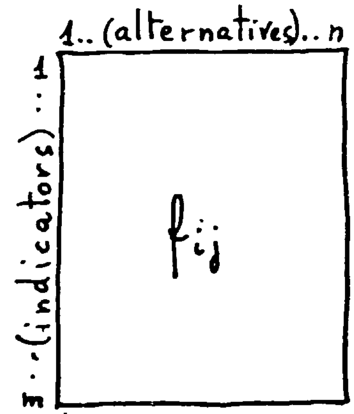
  (b) conflictuality

  (c) participation

  (d) successive elimination

- Starting point :

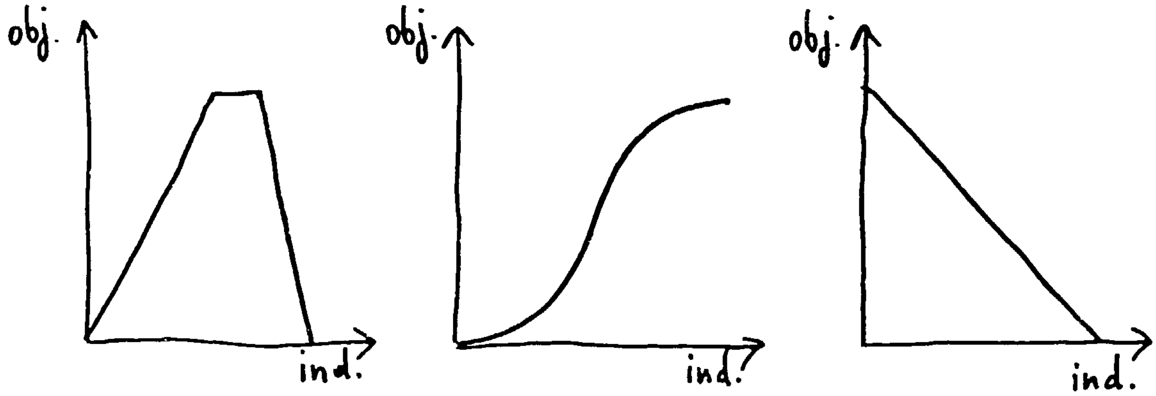
  the impact matrix ⇝



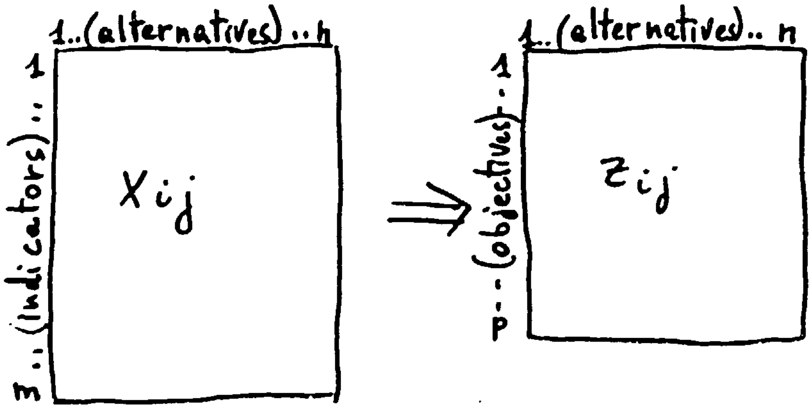
- Methodology :

  multi-attribute analysis

indicators
↳ mutually independent objectives



one indicator → one objective (max)



more than one indicator → one objective

soggettivita' nella valutazione

funzione obiettivo complessiva : somma pesata

$$\max_j f_j = \sum_{i=1}^{p} w_i z_{ij}$$

esempio :

	Alt. 1	Alt. 2	Alt. 3	(w_i)
Obiettivo 1	90	100	80	.20
" 2	100	70	40	.20
" 3	60	80	100	.50
" 4	80	100	90	.10

(z_{ij})

$\Leftarrow w_3 = 0.50$

76	(84)	83	(f_j)

⇓ Alt. 2

- se $w_3 = 0.55$

79	88	88

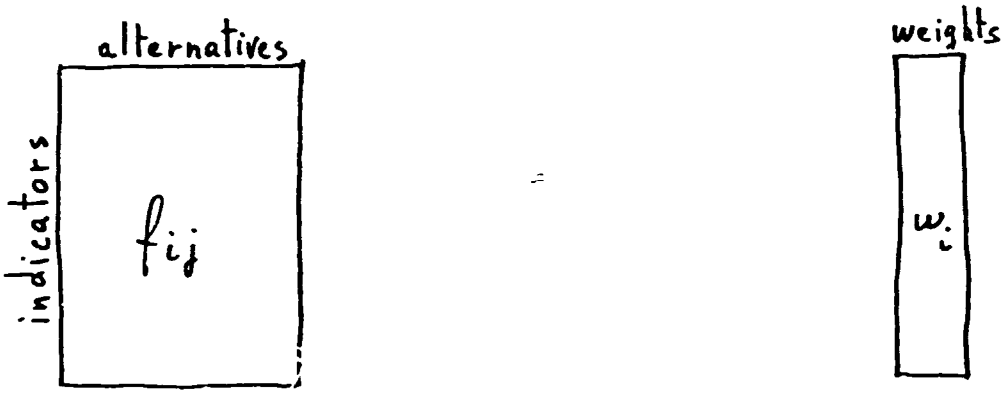
⇝ per $w_3 > 0.55$ è migliore l'alternativa 3

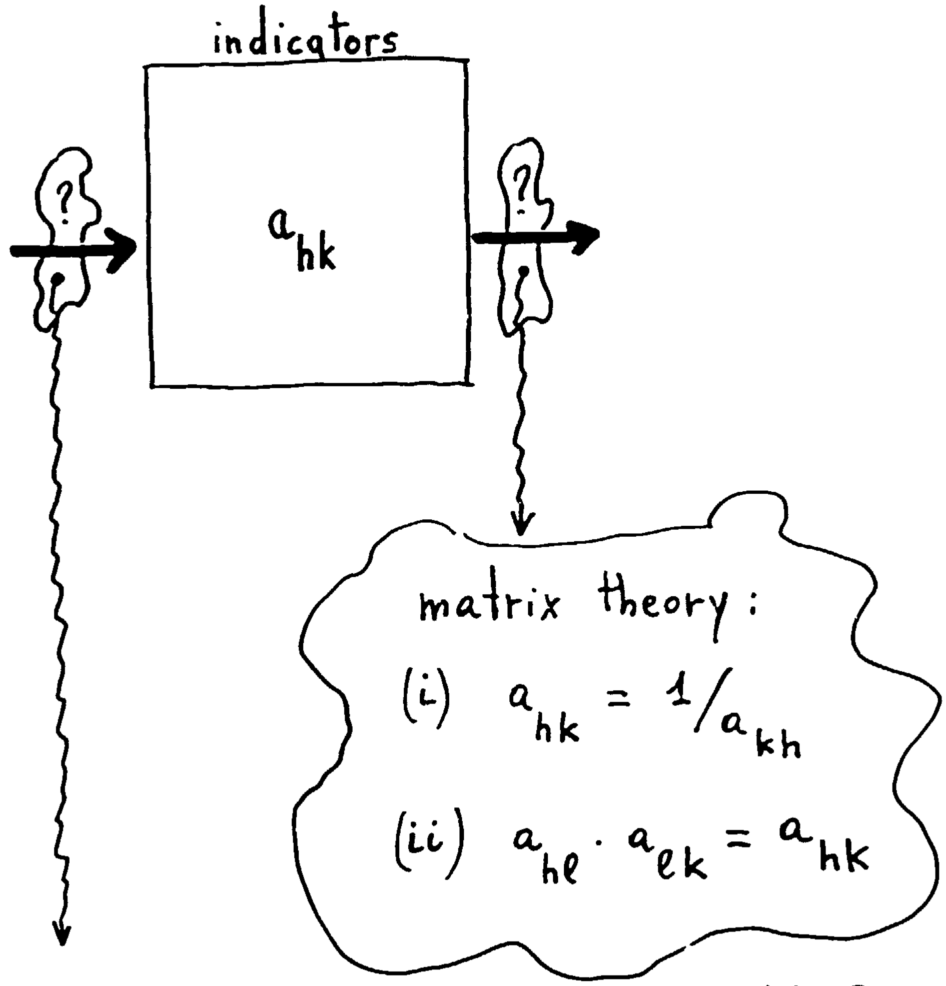
- se $w_3 = 0.10$

52	52	43

⇝ per $w_3 < 0.10$ è migliore l'alternativa 1

Determination of weights by direct comparisons

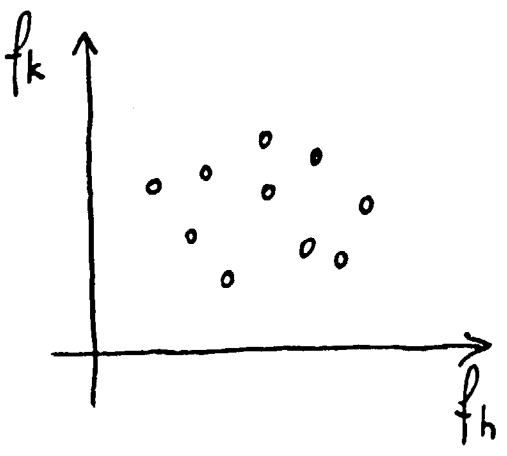


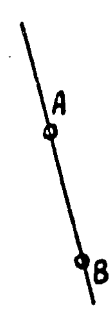


HELP:

what is the substitution rate of indicator h with respect to k ?

MAIN EIGENVECTOR

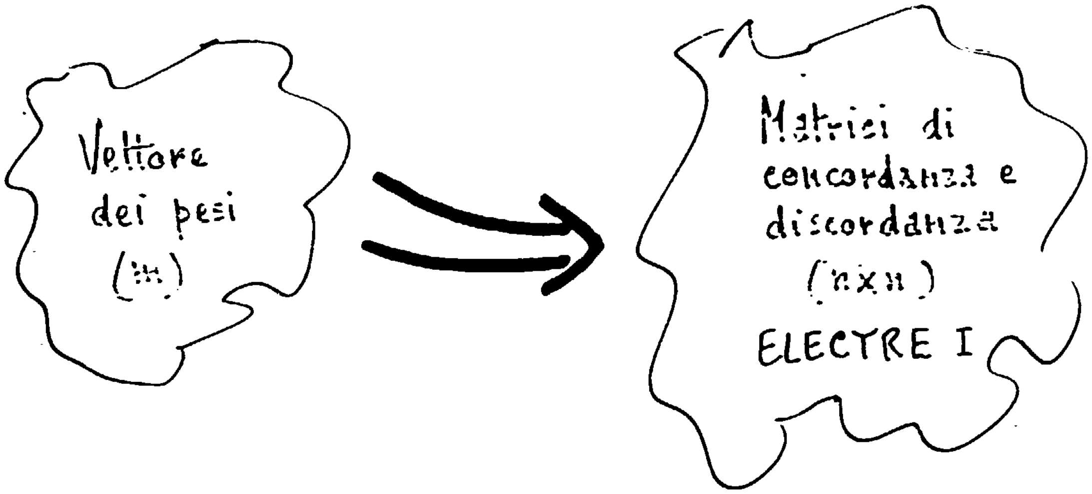




example : $\left|\frac{\Delta f_k}{\Delta f_h}\right| = 4$

(alternative A and B are equivalent)

Concordanza / discordanza



Esempio:

	A_1	A_2	A_3	pesi
c_1	1.	0.6	0.4	0.3
c_2	0.7	0.5	1.	0.4
c_3	0.8	1.	0.8	0.2
c_4	0.8	1.	0.6	0.1

$m = 4$ (indice i)

$n = 3$ (indici r, s)

<u>Matrice C di concordanza</u>: c_{rs} tiene conto di quanto A_r "prevale" su A_s.

	A_1	A_2	A_3
A_1		0.7	0.6
A_2	0.3		0.6
A_3	0.6	0.4	

$\Rightarrow$

$$c_{rs} = \sum_{i \in I_{rs}} w_i$$

$$I_{rs} = \{ i : z_{ir} \geq z_{is} \}$$

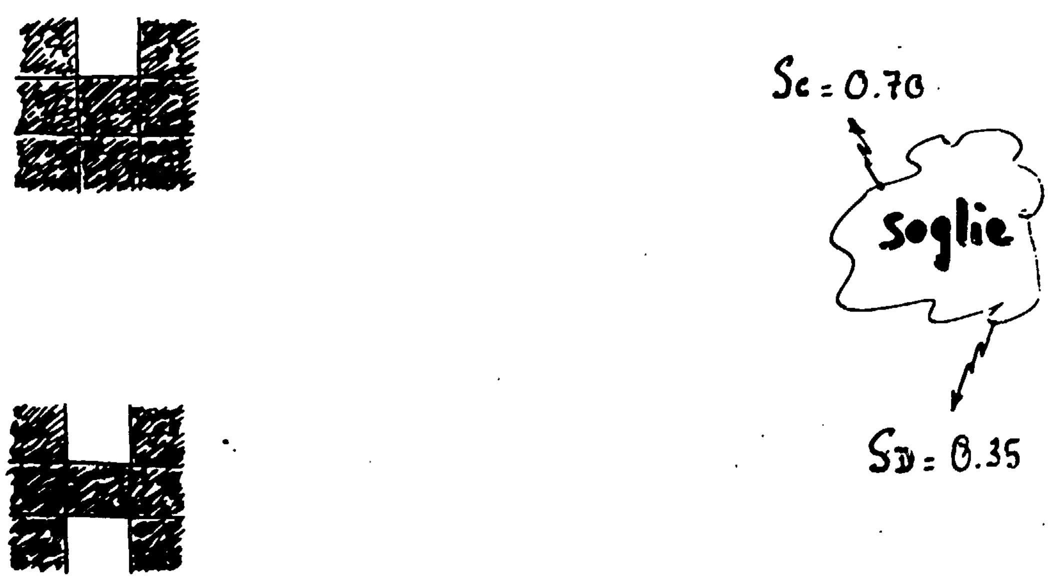
<u>Matrice D di discordanza</u>: d_{rs} tiene conto di quanto "si perde" scegliendo A_r.

	A_1	A_2	A_3
A_1		0.33	0.66
A_2	1.		1.
A_3	1.	0.3	

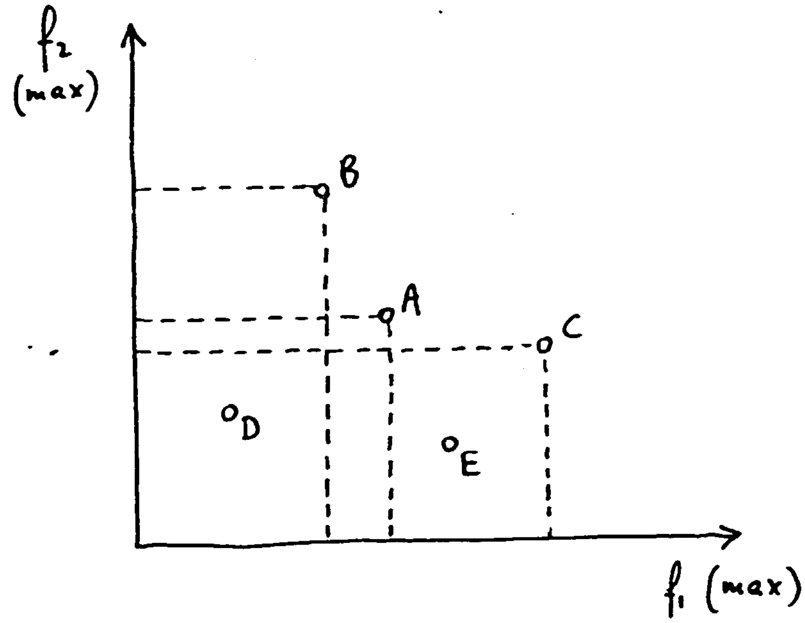
$\Rightarrow$

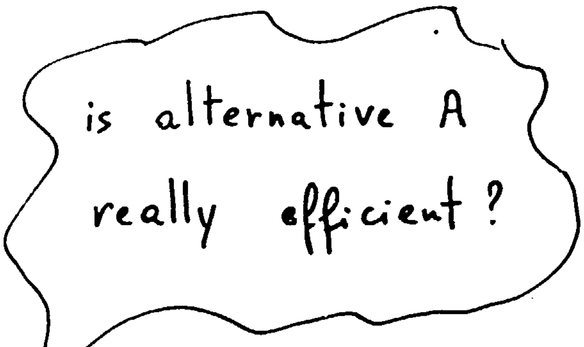
$$d_{rs} = \frac{\max_{i \in J_{rs}} w_i |z_{ir} - z_{is}|}{\max_i w_i |z_{ir} - z_{is}|}$$

$$J_{rs} = \{ i : z_{ir} < z_{is} \}$$


Sc = 0.70
soglie
SD = 0.35

"Weak" dominance : the basic idea





it depends upon :

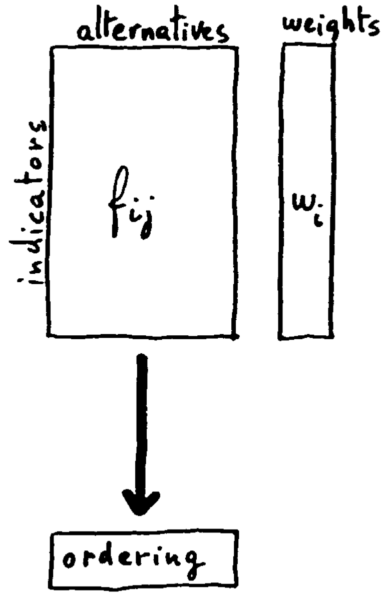
- the vector of weights
- the relative performances $|f_{iA} - f_{ik}|$

Two indexes :

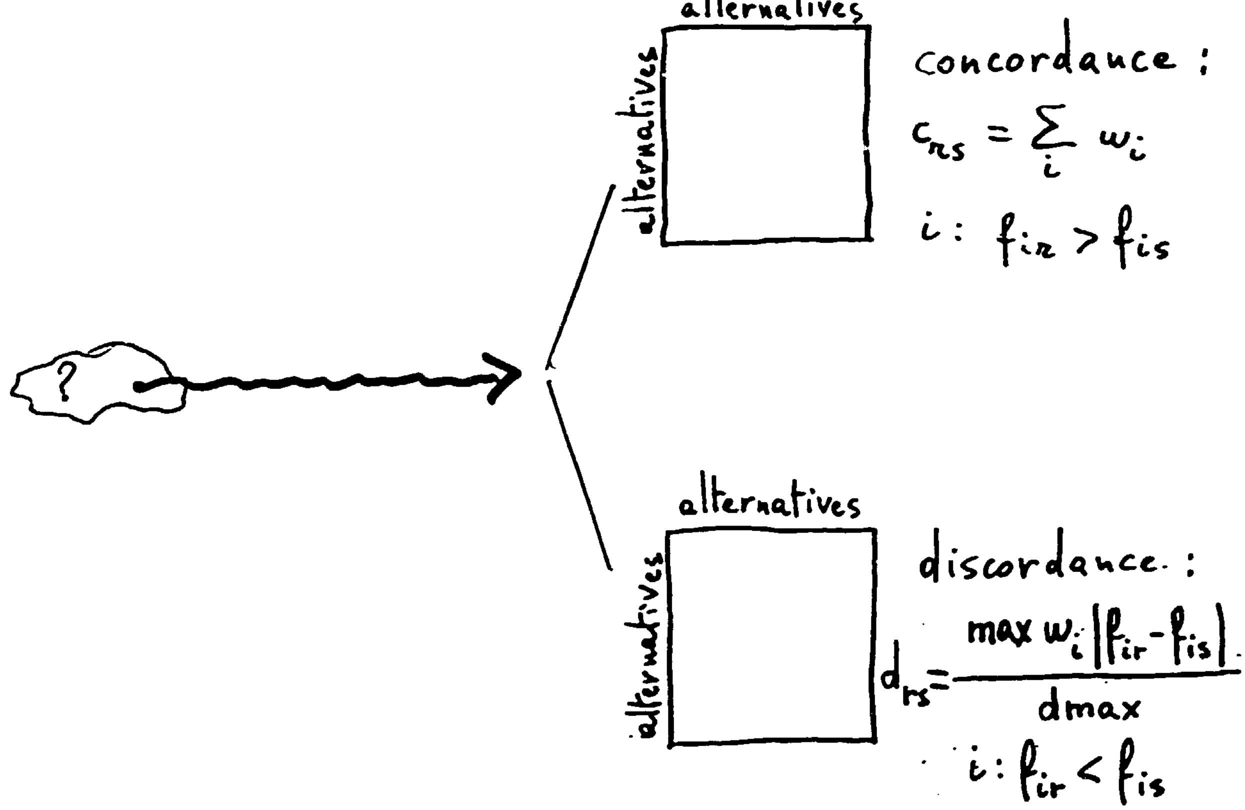
c_{hk} ⇝ concordance (satisfaction)

d_{hk} ⇝ discordance (disappointment)

"Weak" dominance : sensitivity analysis



a


alternatives
alternatives
concordance :
c_rs = Σ_i w_i
i : f_ir > f_is
?
alternatives
alternatives
discordance :
d_rs = max w_i |f_ir - f_is| / dmax
i : f_ir < f_is

□

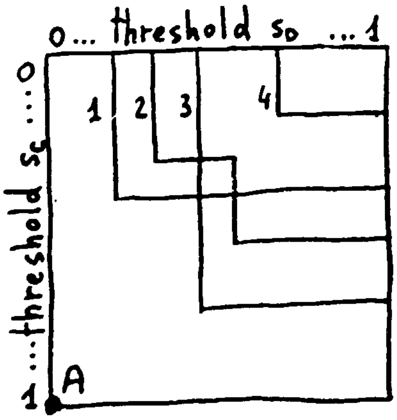
threshold s_c

□

threshold s_D

if $c_{hk} \geq s_c$ and $d_{hk} \leq s_D$

alternative h "weakly" dominates alternative k



weak dominance areas

Point A is the dominance point according to Pareto

Partial orderings

(a) by vector of weights

$$P_j^{(w)} = \sum_i w_i z_{ij}$$

+ sensitivity analysis

(b) by concordance index

$$P_j^{(c)} = \sum_r c_{jr} - \sum_s c_{sj}$$

(c) by discordance index

$$P_j^{(d)} = \sum_r d_{jr} - \sum_s d_{sj}$$

(d) by threshold sensitivity analysis

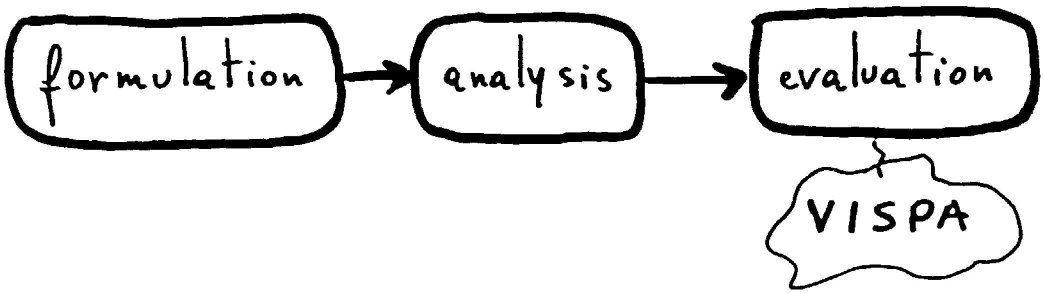
inverted elimination order

(e) the "best" worst case

max min

Conclusions

An integrated framework and a software package



- Applicability

  a <u>real</u> decision making process

  a significant number of < alternatives / indicators

- Features

  low cost (IBM PC)

  repeatibility (and sensitivity analysis)

  interactivity

- Purposes

  information

  rationality

  transparency

  participation

SILVIA: A DECISION SUPPORT SYSTEM FOR ENVIRONMENTAL IMPACT ASSESSMENT

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ABSTRACT. A software package has been developed, containing a methodological framework and a decision support system for environmental impact assessment (EIA) problems. The package is named SILVIA (the acronym, in Italian, stands for Interactive Software for Environmental Impact Assessment) and includes three parts, concerning, respectively, the preliminary phase, the analysis phase and the decisional phase of an EIA procedure. The first part - which is named SERENA - is a data base containing information about Italian environmental legislation, check lists, existing data, available models and methods, previous case studies and bibliographic references. It is being developed at present and is not described here. The second part - which is named GAIA - is based upon spread sheet techniques, and makes it possible to create trees and matrices at different aggregations levels, to coordinate both the results of prediction models and the qualitative estimates and to represent the single steps of the analysis phase. The third part - which is named VISPA - is based upon multi-attribute analysis techniques, including: (a) elimination of dominated alternatives by the Pareto criterion, (b) preference analysis, (c) concordance and discordance analysis, (d) sensitivity analysis. The package has been developed on an IBM-PC and is user-friendly. The interactive procedure all over the steps makes it possible to really involve both the decision maker and the interested groups, in order to clarify the actual entity of conflicts and to provide information aiming and some more rationality and transparency in decision making.

1. INTRODUCTION

Environmental Impact Assessment (EIA) problems are generally characterized by several alternatives, by decision criteria that are not always easy to quantify and by the presence of interest groups with conflicting objectives. These problems thus require interdisciplinary work and great attention to the real development of the decision process [1].

It should be noted, however, that many of the environmental impact "assessments" performed in recent years consist in onerous collections of data, followed by the use of more or less sophisticated methods aiming at predicting some of the effects of a project on the natural, social and economic environment; they were, in fact, more "surveys" than assessments. Moreover, such "surveys" were performed according to different points of view, with no reference to a common standard: this makes comparison of different studies difficult and, even worse, means that it is often impossible for a public authority to really check the adequacy of the impact study. So, the final decision is often the product of intuition and the personal ability of the decision maker rather than the result of a decision process characterized by transparency and the participation of the groups involved.

In a complete environmental impact assessment one can distinguish, from a methodological point of view, three main phases.

The first is a preparatory phase, in which the problem must be correctly formulated: this implies, among other things, an analysis of the environmental standards, of the information available (data, cartography, but also the decision structure, the social groups involved, ...) and of similar previous cases.

The second is an analysis phase, which consists of the following steps: definition of the significant project alternatives and identification of the elementary activities associated with each of them; identification of the environmental sectors which could be affected by any of the alternatives and selection of a set of indicators for each of them; collection of data and, where possible, use of simulation models in order to obtain qualitative or quantitative estimates of the impact of elementary activities on the environmental indicators; aggregation of single estimates in order to forecast the impact of each alternative as a whole on each of the indicators.

Finally, there is an evaluation phase: its crucial aspects are the study of conflicts and the definition of the decision criteria.

The three phases, which do not necessarily follow in this order and can partially overlap, can be repeated several times, with successive levels of refinement.

The SILVIA project (SILVIA is the Italian acronym of Interactive Software for EIA) includes three software packages: SERENA, an expert system which is useful in the orientation and setting up phase of an environmental impact study; GAIA, the aim of which is to organize and represent the logic path and the set of operations necessary to coordinate the analysis and prediction phase; and VISPA, a decision support system based on multi-attribute analysis techniques. GAIA and VISPA can be used independently.

The programmes, which are user friendly, aim at making the technical phases of an EIA study transparent and repeatable. Transparency is obtained through continuous documentation and by saving all the elementary operations step by step; repeatability is guaranteed by the fact that it is possible to change some of the estimates and/or operations and to run the whole study rapidly. Transparency and repeatability are necessary conditions for real control by public authorities and for an effective participation of social groups in the decision process. From the point of view of both the decision maker and the designer, the proposed method is a tool for a logical organization of an EIA study, aiming at reducing time and cost and creating a common language. Here, we briefly present the characteristics of GAIA (Guide to Environmental Impact Analysis) and VISPA (Integrated Evaluation for the Choice between Alternative Projects).

2. GAIA (Guide to Environmental Impact Analysis)

2.1. The Basic Tools for the Analysis

In the analysis phase of an EIA one must in general study and represent sequences of cause-condition-effect relationships [2]: as an example, the ground level concentration of an atmospheric pollutant (effect) is the result of one or more emissions (cause) in a particular atmospheric situation (condition). For this phase, we propose an integrated use of three basic tools: check lists, trees and matrices.

2.1.1. Check lists. Check lists are normally used for the definition of the elements characterising each project alternative and/or the environment. For this purpose a series of disaggregations is performed: in order to describe a project alternative, it is necessary to identify a set of time steps and, for each of them, a set of elementary activities; in order to describe an environment, it is necessary to identify its different components and subcomponents (e.g., the component "atmosphere" can be further subdivided into "meteoclimatology" and "quality", "quality" into "micro" and "macropollutants", and so on). The lists so obtained have a hierarchical structure, i.e. an organization of the items at various levels. Check lists are not exhaustive and cannot be defined once and for all: as an example, the project activities depend on technology (and thus change with technological innovation) and the environmental components depend on the cultural and territorial characteristics of the area under examination.

2.1.2. Trees. Check lists can be represented by special graphs ("trees"), composed of nodes and arcs: the initial node (the only one without predecessors) is called the root and the terminal nodes (with no successors) are called the leaves; to describe the relationships existing between the nodes of a tree, we will use a genealogical terminology: if we are in a particular node, the node from which it originates is its father, the nodes with the same father are its brothers and the nodes which originate from it are its sons. A tree representing a check list can be enriched with further nodes in order to describe a temporal or spatial division or to take into account the possibility of different situations, such as atmospheric conditions or alternative scenarios.

2.1.3. Matrices. The use of matrices makes it possible to represent cause/effect relationships by crossing the nodes of two trees: a column tree, whose nodes indicate the "causes" and a row tree, whose nodes indicate the "effects". Each cell of a matrix thus relates a cause node with an effect node and may contain two pieces of information: a synthetic one, i.e. a number or a symbol, which represents the estimate (qualitative or quantitative) of the effect of the column node on the row node, and a descriptive one, i.e. a documentation of how the estimate was obtained and of its meaning.

2.1.4. The combined use of check lists, trees and matrices. The combined use of trees (enriched check lists taking into account various possible contexts and conditions) and matrices allows us to describe the typical cause/condition/effect relationships of the environmental impact analysis. As an example, the cause node "emission of SO_2" could be disaggregated so as to give rise to several sons associated to different atmospheric conditions (south wind, north wind, ...); similarly, for the effect node "ground level concentration of SO_2", one could have a geographical disaggregation (in district A, in district B, ...). In this example the matrix cells at the most disaggregated level could contain the estimates of the ground level concentration of SO_2 in each district and for each of the atmospheric conditions assumed.

A matrix relates all the nodes of one tree with all those of the other, independently of the hierarchical level in which they are found. Often, however, it is useful to choose, display (as rows or columns of the matrix) and make available for processing, only a subset of the nodes of a tree. The matrix on which one works is therefore generally a submatrix, representing the intersections between the selected subsets of the nodes of the row and the column trees: this allows working on the same matrix at various depth levels, i.e. selecting different submatrices.

2.2. Operations on Trees and Matrices

The main operations which can be performed on a pair of trees and the related matrix are the following.

2.2.1. Construction, modification and documentation of a tree. It is possible to insert, move and cancel both single nodes and subtrees; it is possible to save trees and subtrees so that they can be called again when necessary. One or more documentation screens can be associated with each node.

2.2.2. Selection of rows and columns to display in the matrix. It is possible to "switch on" or "switch off" both single nodes and subtrees of the row and column trees: only the cells concerning the pairs of nodes switched on are displayed in the matrix; the switched off nodes are ignored, but any information contained in non-displayed cells is kept in the memory and is available when required.

2.2.3. Insertion, modification and documentation of estimates. The matrix cells can contain both symbols or words (qualitative estimates) and numbers (quantitative estimates). It is possible to insert, modify or cancel the content of any cell at any time. One or more documentation screens can be associated with each cell containing an estimate.

2.2.4. Conversion of qualitative estimates to numerical values. The problem of performing (and documenting) a transformation of qualitative estimates into numbers is tackled by defining one or more "vocabularies". A vocabulary is a conversion table (from symbols and words to numbers) which can be created and assigned to one or more rows of the matrix. The conversion takes place by applying the related vocabulary to each row; it is a reversible operation, in the sense that one can restore the initial symbols or words at any time. Vocabularies (and relative assignments to rows) can be created, modified, cancelled, documented and saved so that they can be called again and applied when necessary.

2.2.5. Aggregations. Often the estimates obtained by the use of prediction models (qualitative or quantitative) are at a disaggregated level. Let us consider a submatrix whose columns and rows are the elementary activities of the construction phase of an alternative project (cause) and the environmental indicators (effects) respectively: in this case the matrix cells contain the estimates of the effects of each of the single activities on each of the environmental indicators. In order to estimate the overall effect of the set of the construction phase activities on each of the environmental indicators, it is necessary to perform an aggregation, i.e. to replace the columns representing single activities by a unique column representing the whole construction phase. The cells of this column contain, row by row, an estimate obtained by the application of a particular aggregation rule (minimum, sum, mean, weighted mean, ...). In the GAIA package it is possible to assign an aggregation rule to each row (in order to aggregate columns, as in the example cited) or to the columns (in order to aggregate rows); furthermore, it is possible to change, save and call again when necessary any set of aggregation rules (and the relative assignments).

2.3. The Architecture of GAIA

GAIA [3] is organized by projects: each project is defined by one or more alternatives, these in turn can be formed by a combination of constitutive elements.

2.3.1. Project alternatives. The presence of several feasible alternatives makes the decision process significant. As a minimum, there are two alternatives (e.g. to carry out a plan or not); in general, there can be strategic alternatives (e.g. a main road or a railway), which are investigated at the beginning of the decision process; intermediate alternatives (about location, technology, size), which are considered during the design process; minor alternatives (variants or mitigation actions) in the last phase of the decision process, concerning the executive project. Both the analysis phase, by means of the GAIA package, and the evaluation and choice phase, by means of VISPA, can be repeated at different depth levels and at different times..

2.3.2. Constitutive elements. A constitutive element is defined as a component of one or more alternatives, which can be studied, at least in part, autonomously. The subdivision of a main road into segments is a typical example of the use of constitutive elements: some of the impacts (those which do not depend on the project as a whole but only on whether a particular portion of territory is crossed or not) can be studied separately. If a segment is common to several route alternatives, the impacts estimated for it are valid for all the alternatives involved. A constitutive element is however not necessarily a "physical" component of an alternative: it is possible to separate, for instance, the operating phase actions from the construction ones, or the environmental indicators from the territorial, social or economic ones. In any case, the utility lies in dividing a large analysis into a number of homogeneous sections which are easier to handle.

2.3.3. Matrix sequences. An alternative or a constitutive element is represented in the GAIA package by a sequence of matrices, which follow, phase by phase, the logical path of the analysis. A matrix sequence may describe, for instance, a chain of cause/effect relationships: in this case the same tree can be a column tree (causes) or a row tree (effects) in successive matrices. As an example, a chain of cause/effect relationships is that defined by the following pairs of trees: project activity (causes) vs. environmental indicators; environmental indicators vs. environmental indicators (to take into account indirect effects); environmental indicators vs. human activities influenced.

Let us consider now a pair of trees and the related matrix representing a set of cause/effect relationships: it is possible to perform a series of operations on it (enrichment of the trees, selection of nodes, insertion of estimates, conversions, aggregations, ...). The results of each operation can in turn be memorised in a further sequence of matrices, whose rows and columns always have the same meaning. In this case each matrix represents a particular processing phase of the same set of cause/effect relationships.

2.3.4. Generation of alternatives. A matrix representing a complete alternative can be generated at any time by selecting a suitable set of constitutive elements. The programme compares the trees of the single constitutive element matrices and automatically composes the resulting complete alternative matrix, assigning a position in the general frame to each constitutive element with the following rule: if two constitutive elements have the same row tree, the programme places them side by side; if two constitutive elements have the same column tree, the programme forms them into a column. So, the row and column trees of the resulting matrix are the union of the rows and the columns present in at least one of the constitutive elements, respectively. Finally, the programme transfers the estimates contained in the cells of the single constitutive elements matrices into the corresponding cells of the resulting matrix.

2.3.5. The impact matrix. At the end of the analysis of an alternative it is possible to obtain a final vector, i.e. a single column representative of the complete alternative. In this case the column tree has just one node; if the nodes of the row tree are environmental indicators, the matrix cells contain an estimate of the effect of the complete alternative on them.

To compare the alternatives, the programme automatically constructs an "impact matrix", which contains a column for each final vector and a set of rows corresponding to the union of all the nodes present in at least one of the final vectors. The construction of the impact matrix poses a problem: in general the rows of different alternatives are not necessarily coincident. As an example, siting alternatives imply effects in distinct territorial areas; technological alternatives may have effects on different indicators. The cells of the impact matrix will thus be empty whenever an alternative (column) has no specific effect on an indicator (row): the correct content of any empty cell should be the estimate of the effect of the "do-nothing" alternative on the row indicator. For this reason the do-nothing (or "zero") alternative must always be present in the impact matrix and its "effects" must be estimated for all the rows. If the column representing the d nothing alternative is full, the programme automatically assigns, row by row, its estimates to the empty cells of the impact matrix.

2.3.6. The connection with the VISPA package. An impact matrix created by means of the GAIA package can be used as an input to the VISPA package, which organizes the evaluation phase, in which the alternatives are to be compared. For this purpose the only condition is that the matrix must be a numerical one; qualitative estimates must be previously converted into numbers, possibly by means of vocabularies, as already described.

3. VISPA (Choice among Project Alternatives)

The VISPA package [4] is illustrated here by a description of its main logical steps.

3.1. Processing of the Initial Data

The impact matrix is the input data set on which the VISPA package works. It can be obtained from outside (e.g. by means of GAIA) or created autonomously inside VISPA and memorised. It is also possible to memorize and call again an impact matrix on which some operations have already been performed (such as normalization, aggregation and the application of value functions, which will be described below).

3.1.1. Normalization. In an impact matrix the indicators are generally measured in completely different units: the matrix may contain, as an example, social and economic indicators (such as the unemployment rate or the project cost) and environmental indicators (such as suspended particulate per cubic metre or the variety of animal species in an area) [5]. The first operation proposed is thus normalization, i.e. transforming the matrix elements into non-dimensional units, for instance numbers between 0 and 100.

Normalization is a linear transformation, which is carried out row by row. The most usual method is to divide all the cells of a row (i.e., the row indicator values corresponding to the different alternatives) by a suitable normalization value (usually the maximum value). This operation, although essentially technical, should be checked carefully. The numbers obtained depend in fact on the normalization value assumed, which in turn can depend on the alternatives considered. So, the numbers in the normalized matrix could be varied by deliberately introducing some alternative that is not really significant in the decision process, but which can influence the normalization values.

For this reason, in VISPA normalization is an optional operation, which can be performed in various ways, e.g. by introducing normalization values from outside or by defining a reference alternative.

3.2. Transformation of Indicators into Objectives

A crucial step in VISPA is the transformation of indicators into objectives, which can be performed by combining the following two operations: application of value functions and aggregation.

3.2.1. Value functions. The value function [6] of an indicator is defined in VISPA as the relationship between the values that the indicator itself can assume and a non-dimensional measure of the corresponding "satisfaction" or " benefit", expressed in numbers between 0 and 1. So, the application of a value function to a row of an impact matrix yields a set of numbers between 0 and 1, where 1 indicates a maximum "satisfaction" and 0 a minimum "satisfaction" for the effect of a column alternative on the row indicator considered.

In general, the value function may assume any form. In the VISPA package, the user can define a suitable value function for each indicator. As an example, Fig. 1 shows a "bell" function, whose parameters can be fixed by the user interactively with the programme.

3.2.2. Aggregation. It is not always possible to define a value function corresponding to a single indicator. Moreover, complex problems (in which several interests and groups are involved in the decision) are necessarily characterized by a large number of indicators, because, in general, each sector (atmospheric pollution, water pollution, social services, ...) is described by several indicators.

In these cases, a partial aggregation of indicators can be performed, in order to obtain a smaller number of rows which are representative of the various sectors (sector indices). As an example, concerning atmospheric pollution, SO_2, NO_x, suspended particulate and so on may all form a single global air quality index, which contains the information about the overall effect of the set of indicators considered. In general, the sector index is a non-linear function of the indicators, characterized by the presence of synergies.

Aggregation can also be used to reduce the number of objectives, obtaining an aggregated objective from a set of single ones.

3.3. Ranking the Alternatives: the Weighted Sum

In order to rank the decision alternatives, even if partially, it is necessary to estimate the relative importance of the objectives (rows) and thus indirectly of the sectors and interests that they represent. For this purpose, the following steps are made available in VISPA.

3.3.1. Elimination of dominated alternatives. The Pareto criterion makes it possible to eliminate inefficient alternatives, i.e. alternatives that are dominated by some other one: an alternative A is dominated by an alternative B if, for all the objectives considered, the performance of A is not better than that of B and for at least one of the objectives considered the performance A is worse than that of B.

As an example, Fig. 2 considers the performance of five alternatives in relation to two objectives to maximize. It can easily be seen that, as alternatives 1 and 4 are dominated by 2 and 5 respectively, the set of efficient alternatives comprises only alternatives 2, 3 and 5.

Once the programme has determined the dominated alternatives, the user can eliminate them: elimination is optional.

3.3.2. Attribution of weights. To suggest one (or more) vectors of relative weights of the objectives, the technical analyst, the decision maker, the sector experts and the social groups involved require an interactive support.

It has been noted that, even for a small number of objectives (less than 10), it is difficult for anybody to express a vector of relative weights directly. It is easier to perform a series of direct comparisons between pairs of objectives, answering a series of questions such as: how important is objective i compared with objective j ?

However, a technical problem arises: it is possible to obtain a vector of relative weights, equivalent to the set of pair comparisons, only if the answers obtained are "mathematically consistent" [7]. In particular, if the importance of objective i with respect to objective j is a_{ij}, the two properties of reciprocity ($a_{ij} = 1 / a_{ji}$) and consistency ($a_{ik} = a_{ij} \times a_{jk}$) must hold. In real cases it is difficult for the property of consistency to hold, especially if there are many objectives. It is however always possible, by using mathematical methods, to calculate a vector of relative weights, which is an interpretation of the inconsistent answers obtained.

In the VISPA package the user can express the weight vector either directly or by pairwise comparisons. Once a relative weight has been attributed to each row (i.e., to each objective), the VISPA package calculates for each column(alternative) its weighted sum, a number representing the overall behaviour of the alternative itself. So, it could be possible to evaluate all the alternatives under examination, to rank them and possibly to choose the best one. But the result is strongly dependent on the vector of assigned weights, i.e. on a subjective, uncertain and conflictual operation.

3.3.3. Sensitivity analysis. Expressing the weight vector is an uncertain and subjective operation, as it reflects somebody's preferences; it is a conflictual operation, as different decision makers or social groups may give different answers. Therefore, there is little sense in looking for "the optimum solution". Aiming at clarifying the real significance of existing conflicts, it may prove more useful to identify, for each objective, a critical weight interval, outside of which the ranking of alternatives and consequently the final choice would really change, as a function of the weight vector.

Keeping all the weights constant apart from one, VISPA computes the maximum variations (increase and decrease) of this weight that would not alter the ranking and thus not change the final choice. As an example, if the initial ranking among three alternatives were < A, B, C >, corresponding to the attribution of a weight $w_j = 0.15$ to objective j, a possible result of the sensitivity analysis might be:

$$0.06 < w_j < 0.30, \text{ final choice: A,}$$

$$w_j = 0.06, \text{ final choice: C,}$$

$$w_j = 0.30, \text{ final choice: B.}$$

This is a real support to the decision maker, since the programme identifies the objectives such that a reasonable variation of their weight causes changes in the final choice, suggesting that further attention should be concentrated on them and on the really conflicting alternatives.

3.4. Other Ranking Methods and Elimination Phase

A controversial aspect of decision methods is the attempt to determine directly the final choice among a number of feasible but conflicting alternatives. It might prove more realistic to invert such a logic and, instead of looking for the best alternative directly, to eliminate gradually the worst ones, or at least those which are not satisfactory.

For this purpose, one idea is to calculate different rankings of the alternatives according to methods based on different logics (for instance, weighted sum and risk minimization): such a procedure makes it possible to identify the less significant alternatives (the ones placed in the last positions according to any possible ranking) and to eliminate them. Of course, after each elimination, the procedure (and thus the calculation of the various rankings) must be repeated to allow the necessary reconsideration of alternatives whose effects might have been "masked" by others now eliminated.

Let us now consider some of the ranking methods different from the weighted sum that are available in VISPA.

3.4.1. Concordance and discordance matrices. Some of the rankings created by VISPA are based on the calculation of the concordance and discordance matrices [8], whose generic elements c_{hk} and d_{hk} are a measure of "satisfaction" in choosing the alternative h instead of k and of "regret" in giving up alternative k due to h, respectively. Fig. 3 shows, as an example, an impact matrix composed of 3 alternatives and 4 objectives, together with a vector containing the weights attributed to the objectives. In order to compute the concordance and the discordance matrices, the programme compares the alternatives by pairs.

The concordance index c_{hk} of alternative h with respect to alternative k is obtained by summing the weights of the objectives for which h is preferred or indifferent to k. Fig. 4a shows the concordance matrix of the example of Fig. 3.

The discordance matrix can be constructed in a similar way. To calculate the discordance index d_{hk} of alternative h with respect to alternative k, the programme identifies the two rows (objectives) such that the product of the weight of the objective for the performance difference of the alternatives h and k is maximum, among the objectives for which k is preferred to h and among all the objectives respectively. The discordance index d_{hk} is the ratio between the two values thus obtained. The discordance matrix of the example of Fig. 3 is shown in Fig. 4b.

Using the information contained in the two matrices, the programme assigns to each alternative two numbers, the concordance and discordance absolute indices [9], which are computed according to the following definitions:

$$i_h^{(c)} = \sum_j c_{hj} - \sum_i c_{ih}$$

$$i_h^{(d)} = \sum_j d_{hj} - \sum_i d_{ih} .$$

The concordance absolute index of alternative h is a measure of how much it prevails over all the others: the higher its value, the more satisfactory alternative h is. The discordance index is a measure of overall regret in the case where the final choice is alternative h: the lower its value, the more satisfactory h is. Thus two further rankings of the alternatives, based on the absolute index of concordance and the absolute index of discordance respectively, are made available.

3.4.2. Weak dominance. Let us consider two thresholds, of concordance (S_c) and discordance (S_d), respectively: an alternative h can eliminate an alternative k if the two conditions

$$S_c \leq c_{hk}$$

$$d_{hk} \leq S_d$$

hold simultaneously.

Note that if $S_c = 1$ and $S_d = 0$ the two conditions above correspond to the classical Pareto dominance criterion; by decreasing S_c and increasing S_d this criterion is gradually relaxed: substantially a concept of absolute dominance (Pareto) is replaced by a concept of "weak" dominance. It is obvious that the result depends greatly on the threshold values S_c and S_d.

In VISPA the weak dominance concept is used in two ways. In the first, the user fixes the threshold values S_c and S_d and the programme shows the weakly dominated alternatives and, if required, eliminates them. In the second, the programme calculates, for each alternative h, the set of concordance and discordance threshold values such that h is weakly dominated by at least one other alternative. The results of this analysis are shown in Fig. 5. It is obvious that the larger the area in the S_c-S_d plane in which alternative h (h = 1, 2, 3, 4) is weakly dominated, the less satisfactory the alternative is. So, a further ranking ("weak dominance ranking") is obtained.

3.4.3. Other ranking methods. Besides those illustrated up to now, the VISPA package creates a ranking based on a partial weighted sum: the user can select a subset of objectives, for which the programme calculates the weighted sums of the alternative performances and shows the corresponding ranking.

Furthermore, the programme computes two rankings based on the max-min logic: in these rankings, the alternatives such that the "best worst case" and the "best weighted worst case", respectively, occupy the highest positions.

Finally, the VISPA package shows the user all the rankings created in the various steps of the evaluation phase.

3.4.4. Elimination of alternatives. On the basis of information obtained during the various steps, the user can eliminate the unsatisfactory alternatives and/or the less conflicting objectives to concentrate further resources on a more thorough assessment of a reduced matrix (possibly by repeating the preceding steps with suitable variations).

4. CONCLUSIONS

An EIA study implies both technical aspects and subjective criteria. For this reason formalized models and software packages must be flexible, interactive and user friendly; moreover they must favour an integrated processing of qualitative and quantitative estimates.

The SILVIA package organizes an environmental impact study along a precise logical path. The analysis phase is made transparent, thanks to the possibility of documenting and memorizing all the steps, and repeatable, thanks to the possibility of calling the matrices again and rapidly repeating all the processing, modifying some estimates and operations if necessary. As for the evaluation phase, a set of different rankings is proposed, which are obtained according to the fundamental logics of maximizing an aggregate objective function or minimizing some measure of risk or inequality. The programme continuously interacts with the user, especially during the crucial steps of transforming the indicators into objectives and of attributing weights. Finally, the programme performs a sensitivity analysis and makes it possible to iterate the procedure by successive eliminations of the least satisfactory alternatives.

The methodology and the software packages which form the SILVIA project aim at introducing some rationalization and transparency into the decision process, by means of the experimentation of methods that imply a formalization of the procedures and an effective interdisciplinarity from the technical viewpoint and require an active participation of the groups involved from the social viewpoint. In this sense we hope that SILVIA can become a coordinating tool between different technical disciplines and an instrument of communication between the technical and the social worlds.

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FIGURE CAPTIONS (Colorni and Laniado)

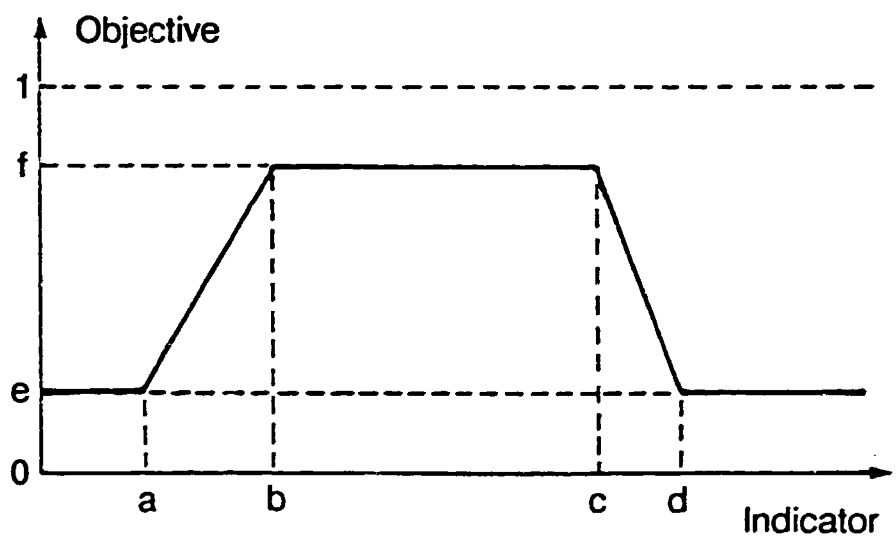
Figure 1. An example of a value function.

Figure 2. The Pareto criterion (see text for explanation).

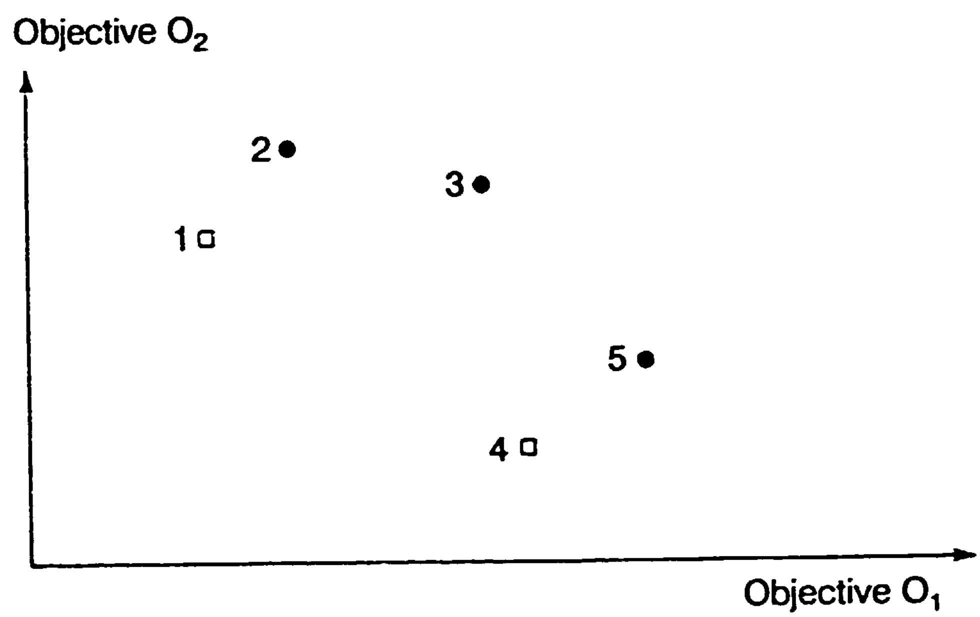
Figure 3. An impact matrix (a) and a weight vector (b).

Figure 4. Concordance (a) and discordance (b) matrices corresponding to the impact matrix of figure 3.

Figure 5. Weak dominance: the weak dominance area of an alternative is the upper right area. In the figure, the weak dominance of alternative 4 is sketched.



Colbran, Lamado, Fig. 1.



Colorni, Laniado, Fig 2.

Coleman, Laniado, Fig. 3.

	alt.A	alt.B	alt.C
obj.1	1.0	0.6	0.4
obj.2	0.7	0.5	1.0
obj.3	0.8	1.0	0.8
obj.4	0.8	1.0	0.6

(a)

weights
0.3
0.4
0.2
0.1

(b)

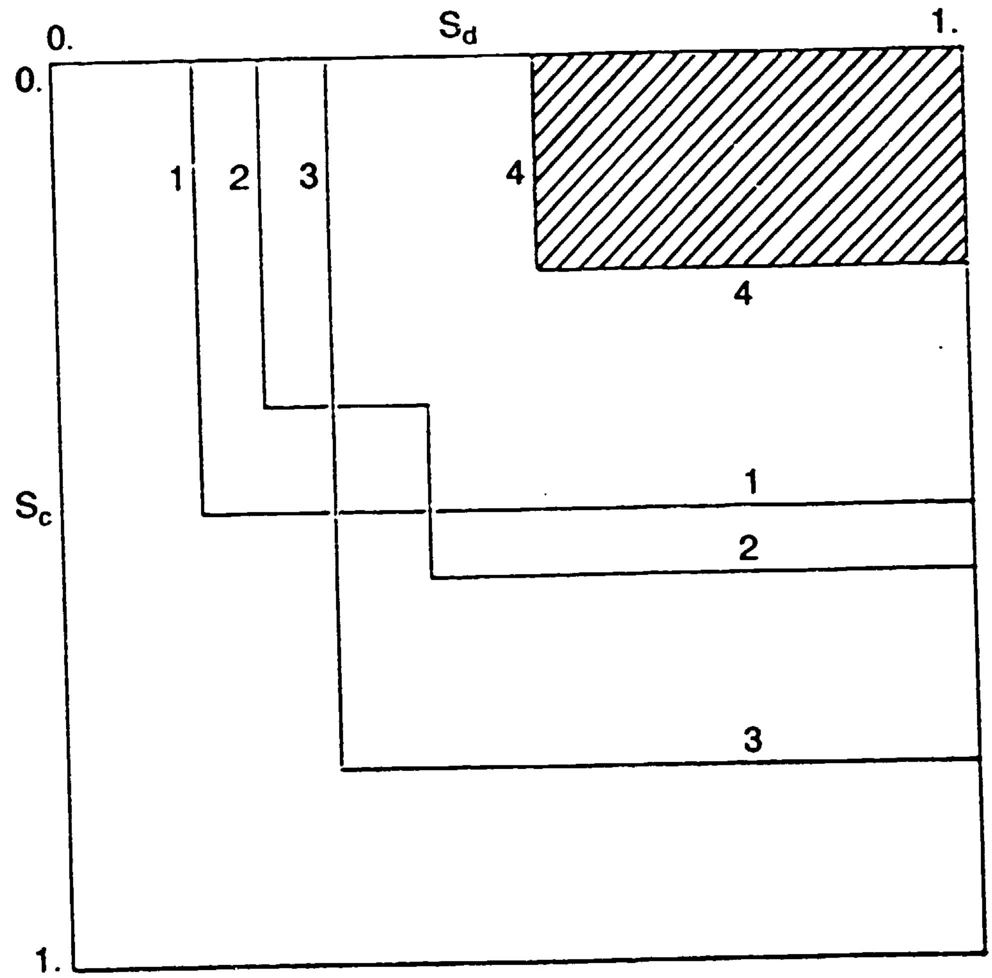
	alt.A	alt.B	alt.C
alt.A	-	0.7	0.6
alt.B	0.3	-	0.6
alt.C	0.6	0.4	-

(a)

	alt.A	alt.B	alt.C
alt.A	-	0.33	0.66
alt.B	1	-	1
alt.C	1	0.30	-

(b)

Coleman, Laniado, Fig 4.



Colborn, Lomnitz, Fig. 5.

Maurizio Spoto & Carlo Franzosini

Natural Marine Reserve of Miramare (Trieste)

THE NATURAL MARINE RESERVE OF MIRAMARE: TOURISM AND ENVIRONMENTAL EDUCATION

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The Natural Marine Reserve of Miramare (Trieste, Italy): Tourism and Environmental Education

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ABSTRACT

During 1989, the management of the marine reserve of Miramare started with the activities that were planned in a programme of environmental education (project 'Scuolambiente'); and introduced activities on behalf of a large tourist public (project 'Seawatching'). These included a visit centre, an information office, a centre for environmental education, and promotional materials presenting the various services that are on offer. Visitors in that year numbered 16 730, 300 *of which participated in guided marine visits, and* 4430 *of which were school visitors interested in the programmes of environmental education.*

INTRODUCTION

The designation of protected marine areas in Italy is a recent development. In 1982, the government passed a law which embodied a general project for the protection of national seas; but it was not until 1986 that the law began to operate by the decrees for the institution of the first two marine reserves in Italy: the island of Ustica, near Sicily, and the area of Miramare in the Gulf of Trieste.

The natural reserve of Miramare is a protected coastal area, situated in the Gulf of Trieste (in the northern Adriatic Sea), 8 km north-west of the town of Trieste.

The area of the reserve is some 30 hectares. The coast comprises

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karst limestone, a characteristic rock of the 'Carso' of which the Miramare promontory is a small part. The white castle of Miramare overlooks the promontory; built in 1860, for Maximilian of Habsbourg, and at present it is a renowned tourist destination.

The bottom of the reserve appears rocky, pebbly and sandy out to depths of 6–8 m; further out, it becomes muddy. The maximum depth is 18 m. The marine reserve embodies the majority of the sea-weed associations of the Gulf of Trieste; and the prohibitions currently in force favour the presence of many characteristic fish species.

The management of the marine reserve has been entrusted to the Italian Association for the Worldwide Fund for Nature, on the basis of a special convention stipulated in 1987 by the Ministries of Environment and the Mercantile Marine.

In 1987–1988, the first government financial support became available to help set up the marine reserve. With effect from 1990, annual financing will cover the normal outlay for personnel and the over-all management expenses. The operational management of the reserve is handled by a cooperative of biologists, naturalists, scuba-divers, technicians, nature and scuba guides. At the present time, four people are employed full-time, while several others are employed part-time or are voluntary workers; three are conscripts in the civil service.

Research and education are the main purposes of the reserve, and these are carried out in cooperation with the Laboratory of Marine Biology of Aurisina (Trieste). Also, in order to increase the public awareness of the activities of the marine reserve, and the preservation of marine environments, there is a visit centre, an information office and such facilities as a terrestrial 'nature pathway'. These were equipped in 1989 to serve tourists visiting the reserve, the castle and the park of Miramare.

MANAGEMENT PURPOSES AND METHODS

The activities programmed for the Miramare marine reserve concern the conservation, research and cultural objectives required by the law passed in 1982. The management plan is based on various sub-projects: educational–interpretation, scientific, and adequate reserve protection.

The sub-project relating to environmental education and interpretation, including some general visiting activities, was the first to be set out. With this programme, it was possible to achieve the following management purposes:

- (a) to improve knowledge of a protected marine environment for the local people, including a clear understanding of the prohibitions relating to conservation;
- (b) education of young people, using adequate didactic programmes for schools of various levels;
- (c) promotion of new forms of exploitation of the natural environment for educational tourism;
- (d) creation of new jobs in connection with the reserve, or with certain external activities also concerning the reserve;
- (e) to involve the public administration services in long-term projects in environmental education;
- (f) a proposal to enlarge the protected marine and coastal areas in the Gulf of Trieste, based on the Miramare reserve model.

In the programme of environmental education and interpretation, the following systems have been used:

- (a) terrestrial guided and self-guided visits along the coastal nature paths;
- (b) marine scuba and snorkelling visits, always under guidance, along underwater nature paths;
- (c) facilities for visits and visitors' reception, such as the information office and visit centre;
- (d) classroom and laboratory for marine environmental education;
- (e) programme of didactic activities for the schools;
- (f) promotional and divulgative material, presenting the various services offered by the reserve to the visitors.

ORGANIZATION OF VISIT ACTIVITIES

(a) *Guided and self-guided visits along the coastal nature-path.* The promontory of Miramare encloses a botanical garden which contains exotic and also autochthon species, characteristic of the Carso, of which Miramare is a protrusion in the Gulf of Trieste. The nature trail takes account of these botanic features and also offer panoramic views of the landscape surrounding the protected area. The terrestrial visit can be led by one staff member of the reserve (fee-paying), or self-guided using a leaflet.

(b) *Guided marine visits with aqualung or by snorkelling.* Although the protected area is limited to 30 hectares, it has been possible, thanks to a rational zoning, to develop an underwater path for scuba-divers and for visitors who wish instead to snorkel. These visits are always guided, are carried out on certain days of the week and in specific periods of the year, and are numerically limited, in order to reduce the impact within the protected environment. A talk with slides precedes the marine circuits. The walks pass through different habitats of the reserve, offering to the visitor a direct contact with the protected flora and fauna characteristic of the Gulf of Trieste; and giving the visitor the opportunity to adjudge the effectiveness of the environmental protection effort. Visits involve payments (an entrance charge) for the reimbursment of the guides and other expenses sustained by the reserve.

(c) *Visit centre and information office.* Even the non-swimming visitors could appreciate some of the forms of marine life present in the protected area. In the visit centre, situated in an historical building, there is an aquarium hall, and a hall with panels illustrating the hydrological and geological features of the Gulf of Trieste. By mid-1991, some TV monitors connected with underwater cameras will show the life on the bottom of the reserve. The camera system replaces the use of boats with transparent hulls, which are unsuitable for such a small area and are periodically affected by a high degree of water turbidity. The information office provides details on the guided and self-guided visits in the park.

(d) *Centre for environmental education.* In the course of the academic year, activities involving the schools of the town of Trieste, and the whole region of Fruili-Venezia Giulia, are vigorously pursued. The reserve offers complete didactic programmes which include half-day or one day guided excursions along the coasts of the gulf (marine, karstic–coastal and lagoon environments), practical didactic work in the field, or in the educational laboratory.

One important activity in the centre for environmental education was a project supported by the municipal administration of the town of Trieste, called 'Scv ılambiente' (school-environment). This project, which began in April 1989, includes practical and theoretical activities concerning the local marine environment. In this way, the reserve was able to influence the public administration as to problems regarding the protection of the marine environment; and through the students, to inform the local population as to the diversity of activities organized by the reserve. In fact, some of the private visitors coming to visit the centre during the week-end are those same students, along with parents.

(e) *The programme of didactic activities in the reserve.* The didactic activities organized in the centre of environmental education are addressed to schools of all kinds with programmes set at different levels. They include:

—half-day or one day excursions;
—practical work in the field, for instance the observation of the tidal environment, where the students learn to identify the major organisms living in this extreme environment;
—didactic cruises which include measurements of sea-water and climatic parameters and the collection of plankton samples;
—laboratory observations of the organisms collected in the field.

All of the activities of the didactic programme can be carried out in a study week for schools a long distance away, making use of a youth hostel near Miramare marine reserve.

(f) *Promotional and divulgative material.* Each activity and service organized by the reserve, especially the didactic ones, are presented in information leaflets. Particular attention was directed at a series of handbooks written for the observation of underwater environment. In these handbooks, the simple techniques of snorkelling are described. With the aid of a waterproof handbook the identification of the major marine species is possible.

TYPOLOGY OF THE VISIT ACTIVITIES

During 1989, several types of visits were organized and coordinated among the component sections. Based on a general evaluation, and considering the services requested, it is possible to divide the visitors into the following categories:

(a) *Scuba visitors*: These are usually members of scuba-diver associations. Numerically, they are not an important category, but a demanding one, since they always require a guided service; for this reason, the reserve is provided with guides trained in a course held by the National Association of Scuba Divers Instructors, who are trained to accompany groups of scuba-divers and in first aid.

The number of visits with aqualung is limited to 25 in the period from April to October, for one group of ten scuba divers per week. Scuba visitors during 1989 numbered 250.

(b) *Visitors interested in guided tours*: In this category, there are visitors who are interested in problems regarding the sea and want more information than those using the visit centre; for this kind of visitor, special slide presentations and seawatching activity have been organized. 'Seawatching' is a snorkelling tour, but led by a nature guide inside a protected marine area (both governmental ones, such as Miramare, and privately-owned ones, such as the six 'Oasi blu' managed by the WFN along the Italian coasts), with explanatory aids such as slide material and a waterproof illustrated handbook. Visitors on guided tours, during 1989, numbered about 50.

This new activity, designed for the public at large, was inaugurated at Miramare in July 1989, and the data refer to the period up to the end of 1989. At the moment, the practice of 'seawatching' is open to groups of no more than eight persons, twice per week, in the period June–September.

(c) *School visitors*: This category is the most important for certain periods of the year; and requires the service of a nature guide. It also involves a self-guided visit in the exhibition halls of the reserve and via the nature paths. These visitors are always organized into school classes, and in 1989 numbered 4430.

(d) *Private visitors*: This is numerically the most important and heterogeneous category considering age, culture, and environmental sensitivity. These visitors profit only from the self-guided services in the visit centre and on the outer nature paths; they request reception and information assistance services for the self-guided visit. The presence of one member of staff in the exhibition halls, for the distribution of informative material and for giving explanations, has proved important. For this category of visitors, short walks at the visit centre, including a videofilm and a slide projection, have proved popular. In 1989, the number of private visitors totalled some 12000. The overall total of visitors to Miramare marine reserve was some 16730.

CONCLUSIONS

The touristic and environmental education projects, such as 'Seawatching' and 'Scuolambiente', promoted by the marine reserve of

Miramare in collaboration with the management of WFN-Italy, are aimed to affect a large number of people. Only through the knowledge of the diversity of marine forms of life, and of the complex equilibriums they are involved in can people understand the necessity to regulate, and to control certain human activities. The institution of several protected marine areas is part of these regulations.

Continuous updating of the programmes of environmental education, and careful surveys of the impact of the marine visits, will be essential.


Parco
marino di
Miramare

TABLE 1. A Checklist for Planning and Implementing a Protected Areas Programme

Preliminary Planning
1. Interpret policy and legislation
2. Organise the planning agenda
3. Identify the planning teams
4. Define programme objectives
5. Define identification and selection criteria

Result: *a planning team with a policy and legal framework to guide and support the developing programme*

Systems Planning
1. Collect and map basic species and habitat information at the national level
2. Classify marine and coastal environments and habitats
3. Identify candidate sites
4. Define protection categories
5. Apply selection criteria
6. Select sites

Result: *protected areas selected for the national system*

Site Management Planning
1. Survey site in detail
2. Identify areas with greatest value for different uses
3. Prepare zoning plan
4. Identify infrastructural, equipment, financial, and management needs
5. Prepare management plan
6. Initiate process of legal declaration of protected area

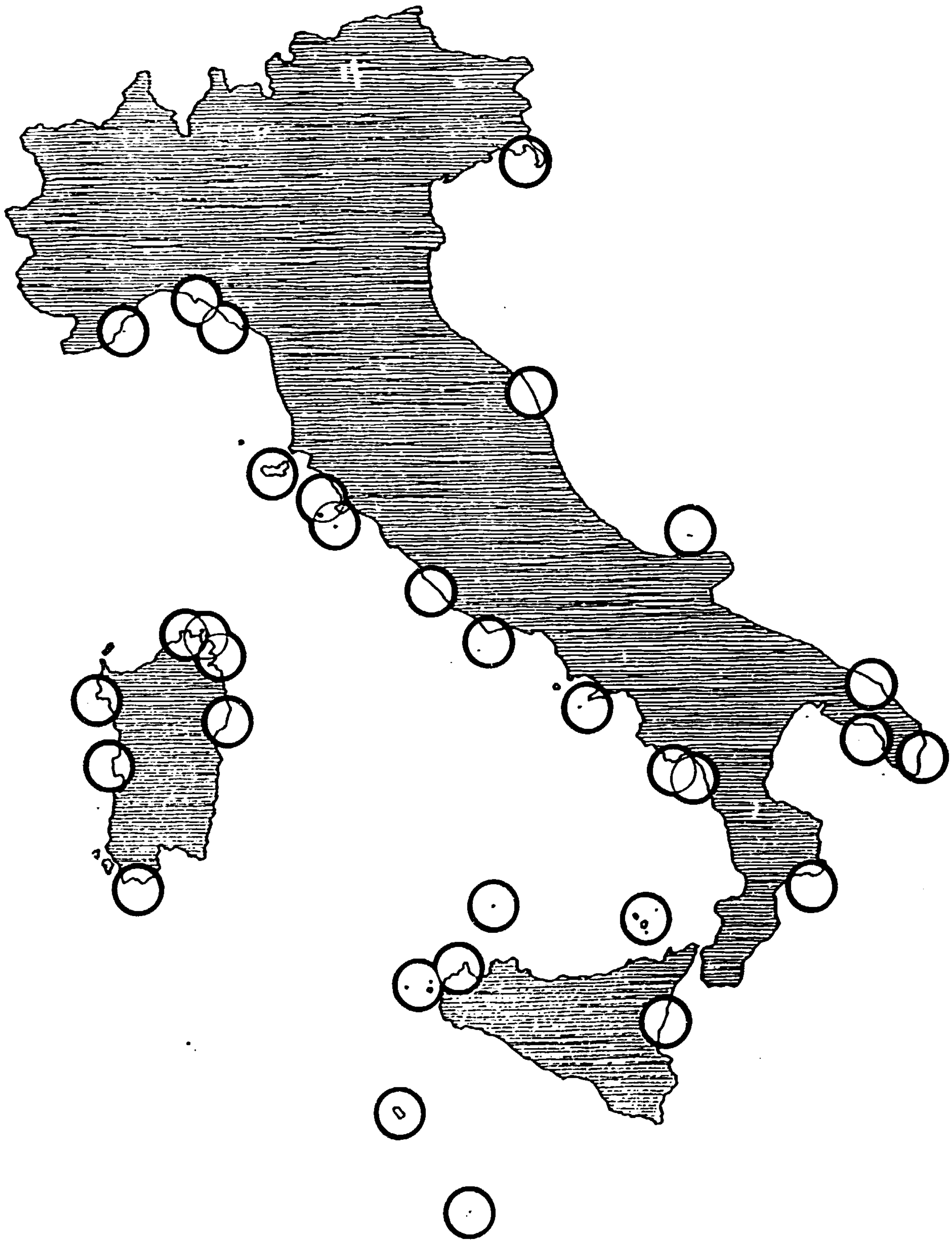
Result: *a comprehensive site implementation programme*

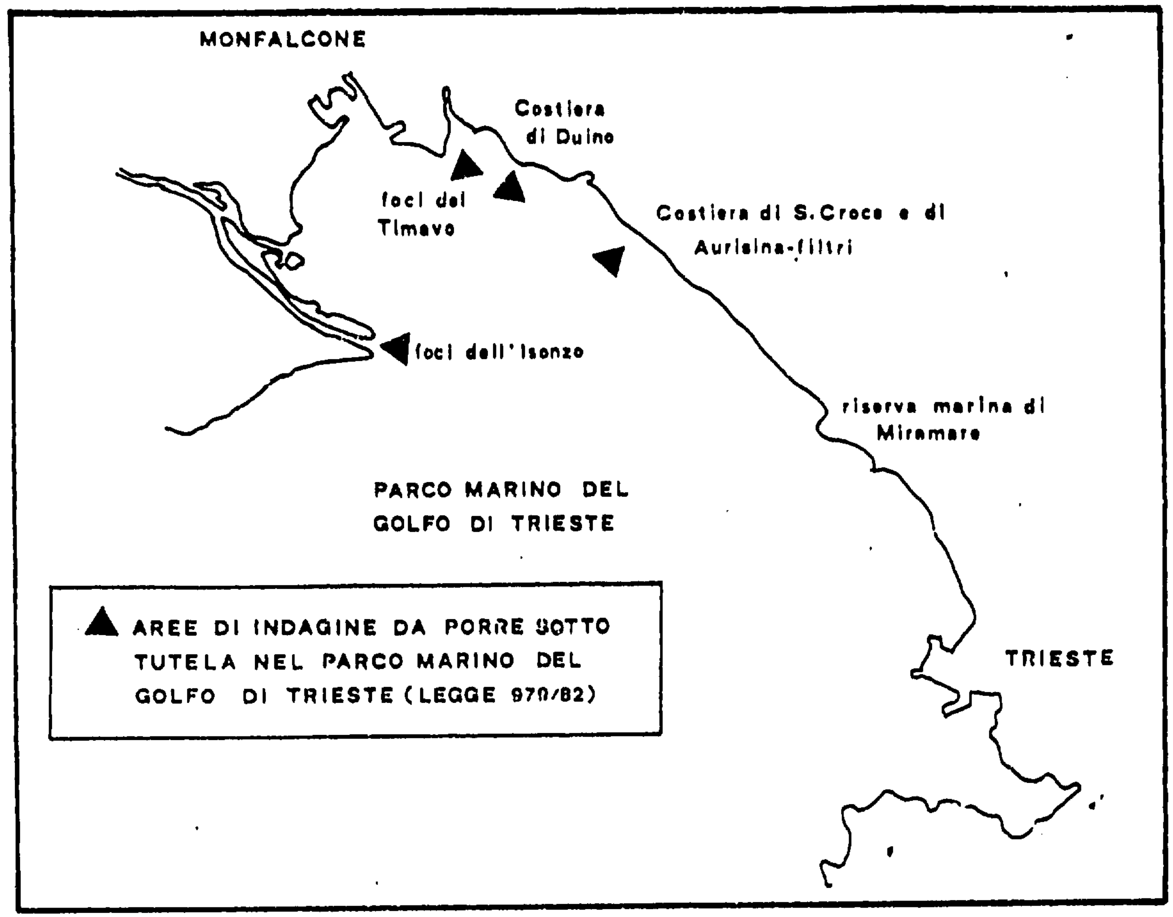
Site Administration and Management
1. Build facilities, purchase equipment, and hire personnel on a scale consistent with available funds
2. Implement management prescriptions
3. Begin interpretation programmes
4. Begin surveillance and enforcement
5. Conduct monitoring studies and encourage research
6. Review and if necessary revise management plan

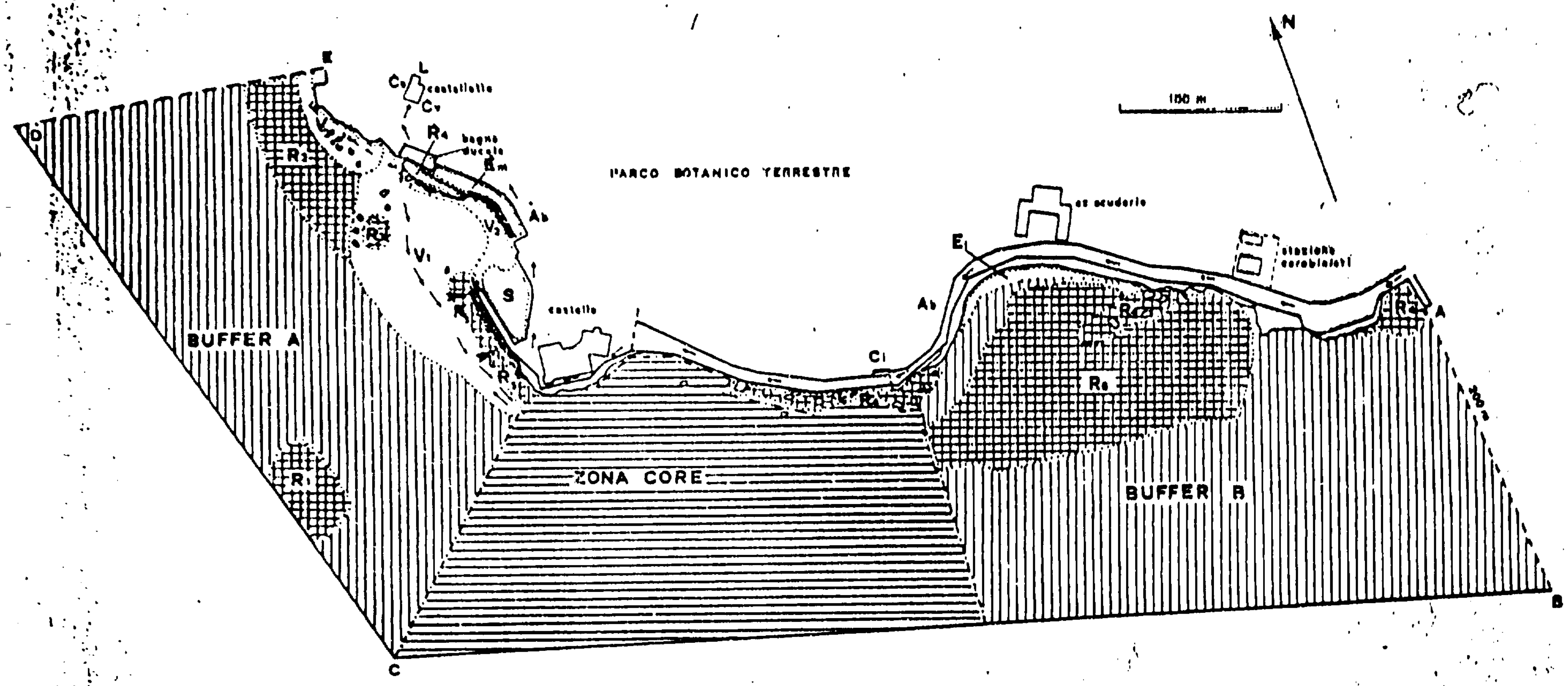
Result: *an operational protected area site*

3. *System planning* looks broadly at programme goals and objectives and provides the criteria for identifying and selecting sites (see below).
4. *Site planning* provides the initial site design, including use zoning, and the management plan for each protected area in the system, and for future revisions as needed (see Section 4).
5. *Implementation and management* develop, administer, manage, and improve the protected area site (see Section 4).

Under ideal conditions, preliminary planning is completed first, followed by system planning and, finally, site management planning. However, such logical progression seldom occurs in the real world. Often, areas will be protected

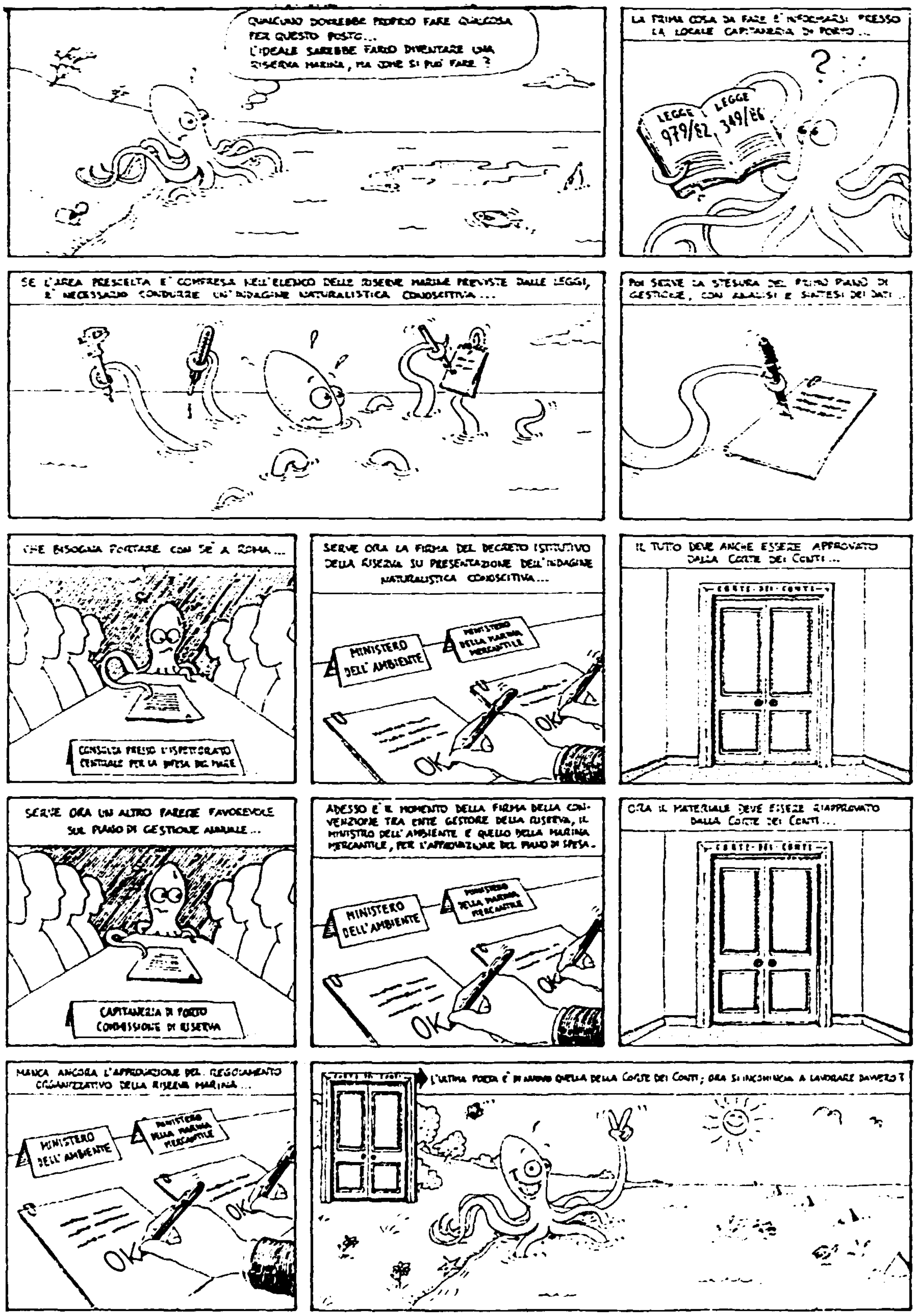



MONFALCONE
Costiera
di Duino
foci del
Timavo
Costiera di S.Croce e di
Aurisina-filtri
foci dell'Isonzo
riserva marina di
Miramare
PARCO MARINO DEL
GOLFO DI TRIESTE
TRIESTE
AREE DI INDAGINE DA PORRE SOTTO
TUTELA NEL PARCO MARINO DEL
GOLFO DI TRIESTE (LEGGE 979/82)

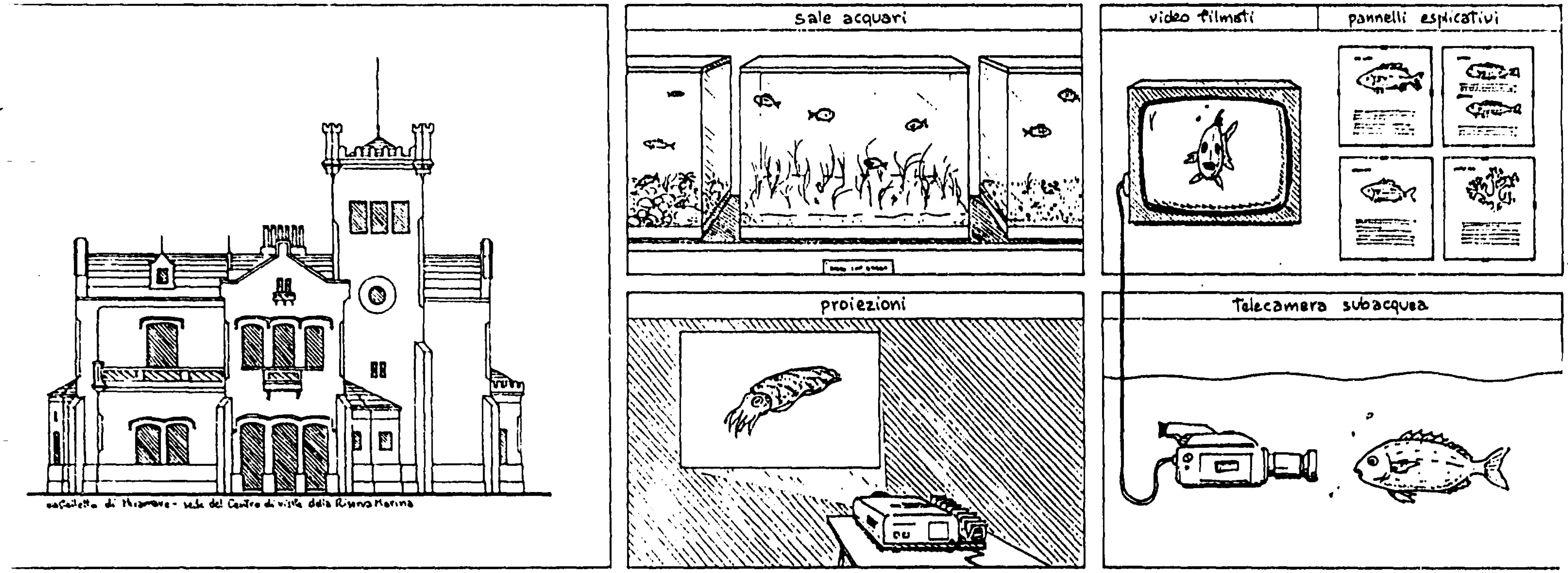


LEGENDA PRIMA ZONIZZAZIONE RISERVA MARINA DI MIRAMARE

V_1 visite con autorespiratore
V_2 visite in sea-watching
R_1 area di studio sulle barriere artificiali
R_2 a. di s. sulle biocenosi delle sabbie
R_3 monitoraggio in continuo parametri chimico fisici acque
R_4 a. di s. di ecologia intertidale
R_5 a. di s. sulle litocenosi sciafile
R_6 a. di s. sulle fanerogame marine
R_7 a. di s. eco etologico sulle specie ittiche di scogliera
C_v centro di visite
Ab aula blu
C_e centro di educazione all'ambiente marino
S area di uso generale
E_m area educativa sull'ambiente di marea
E_i a. e. sulla fauna interstiziale
BCD capisaldi di confine con gavitelli luminosi
B rilevamento vero 350°
C r. v. 46°
D r. v. 97°
telecamera subacquea
itinerario naturalistico subacqueo
i. n. terrestre
BUFFER zone cuscinetto laterali



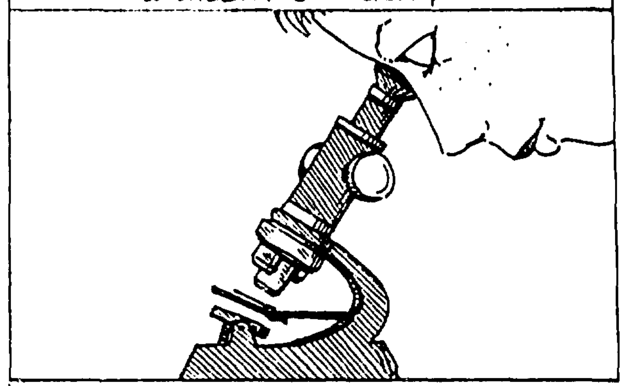
QUALCUNO DOVREBBE PROPRIO FARE QUALCOSA PER QUESTO POSTO... L'IDEALE SAREBBE FARLO DIVENTARE UNA RISERVA MARINA, MA COME SI PUÒ FARE ?
LA PRIMA COSA DA FARE È INFORMARSI PRESSO LA LOCALE CAPITANERIA DI PORTO ...
LEGGE 979/82
LEGGE 349/86
SE L'AREA PRESCELTA È COMPRESA NELL'ELENCO DELLE RISERVE MARINE PREVISTE DALLE LEGGI, È NECESSARIO CONDURRE UN'INDAGINE NATURALISTICA CONOSCITIVA ...
POI SERVE LA STESURA DEL PRIMO PIANO DI GESTIONE, CON ANALISI E SINTESI DEI DATI ...
CHE BISOGNA PORTARE CON SÉ A ROMA ...
CONSULTA PRESSO L'ISPETTORATO CENTRALE PER LA DIFESA DEL MARE
SERVE ORA LA FIRMA DEL DECRETO ISTITUTIVO DELLA RISERVA SU PRESENTAZIONE DELL'INDAGINE NATURALISTICA CONOSCITIVA...
MINISTERO DELL'AMBIENTE
MINISTERO DELLA MARINA MERCANTILE
OK
IL TUTTO DEVE ANCHE ESSERE APPROVATO DALLA CORTE DEI CONTI ...
CORTE DEI CONTI
SERVE ORA UN ALTRO PARERE FAVOREVOLE SUL PIANO DI GESTIONE ANNUALE ...
CAPITANERIA DI PORTO COMMISSIONE DI RISERVA
ADESSO È IL MOMENTO DELLA FIRMA DELLA CONVENZIONE TRA ENTE GESTORE DELLA RISERVA, IL MINISTRO DELL'AMBIENTE E QUELLO DELLA MARINA MERCANTILE, PER L'APPROVAZIONE DEL PIANO DI SPESA.
MINISTERO DELL'AMBIENTE
MINISTERO DELLA MARINA MERCANTILE
OK
ORA IL MATERIALE DEVE ESSERE RIAPPROVATO DALLA CORTE DEI CONTI ...
CORTE DEI CONTI
MANCA ANCORA L'APPROVAZIONE DEL REGOLAMENTO ORGANIZZATIVO DELLA RISERVA MARINA ...
MINISTERO DELL'AMBIENTE
MINISTERO DELLA MARINA MERCANTILE
OK
L'ULTIMA PORTA È DI NUOVO QUELLA DELLA CORTE DEI CONTI; ORA SI INCOMINCIA A LAVORARE DAVVERO !



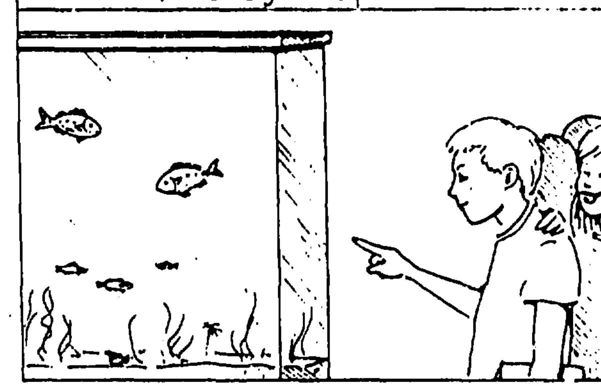
castelletto di Miramare - sede del Centro di visita della Riserva Marina

castello di Miramare - Sede del Centro di educazione all'ambiente marino

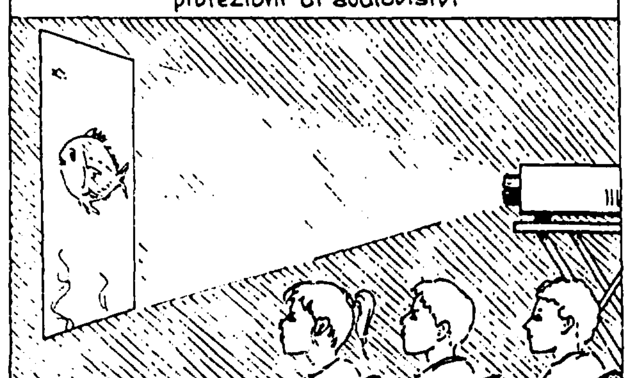
osservazioni al microscopio



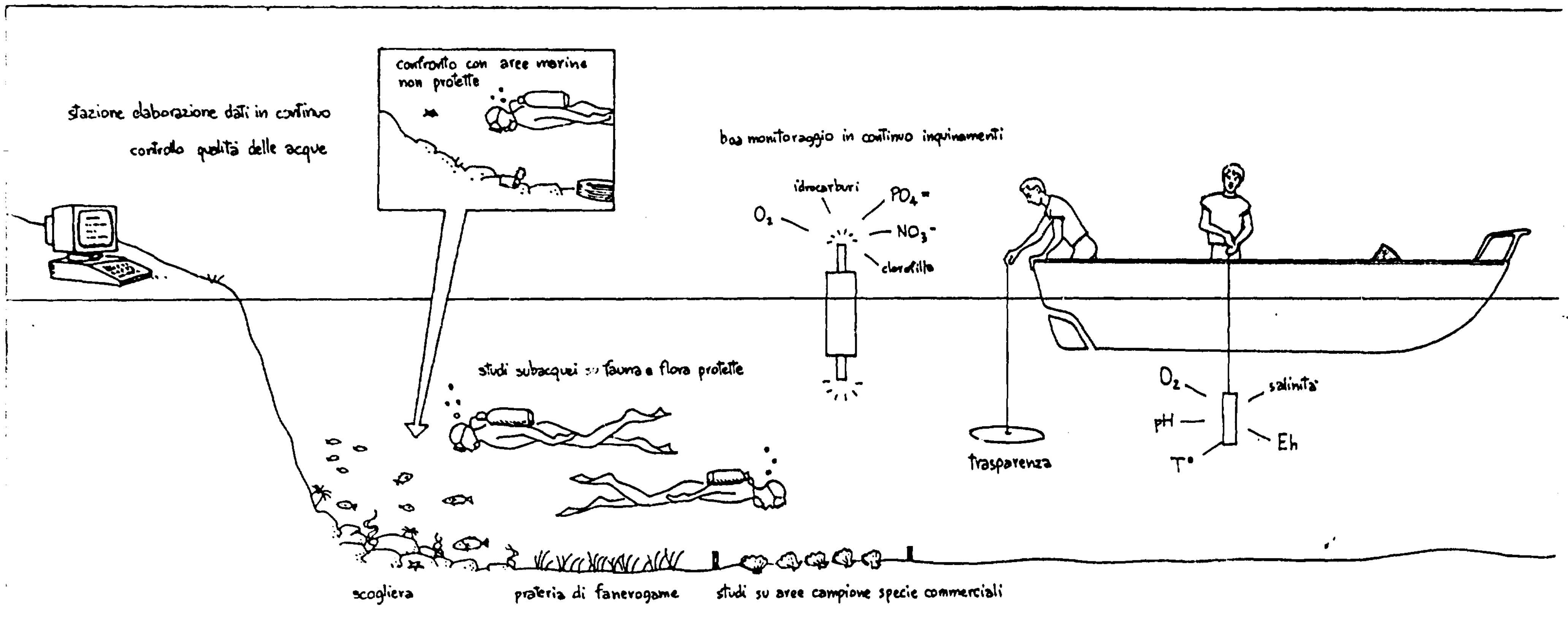
visita agli acquari

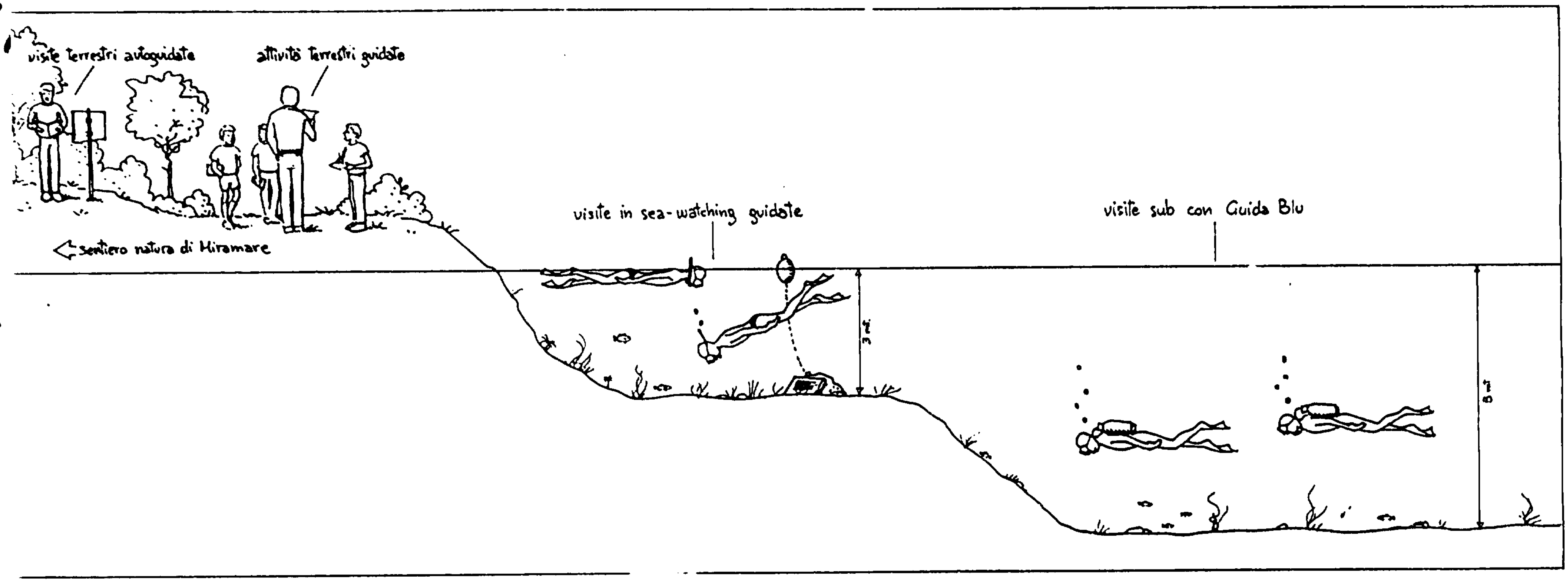


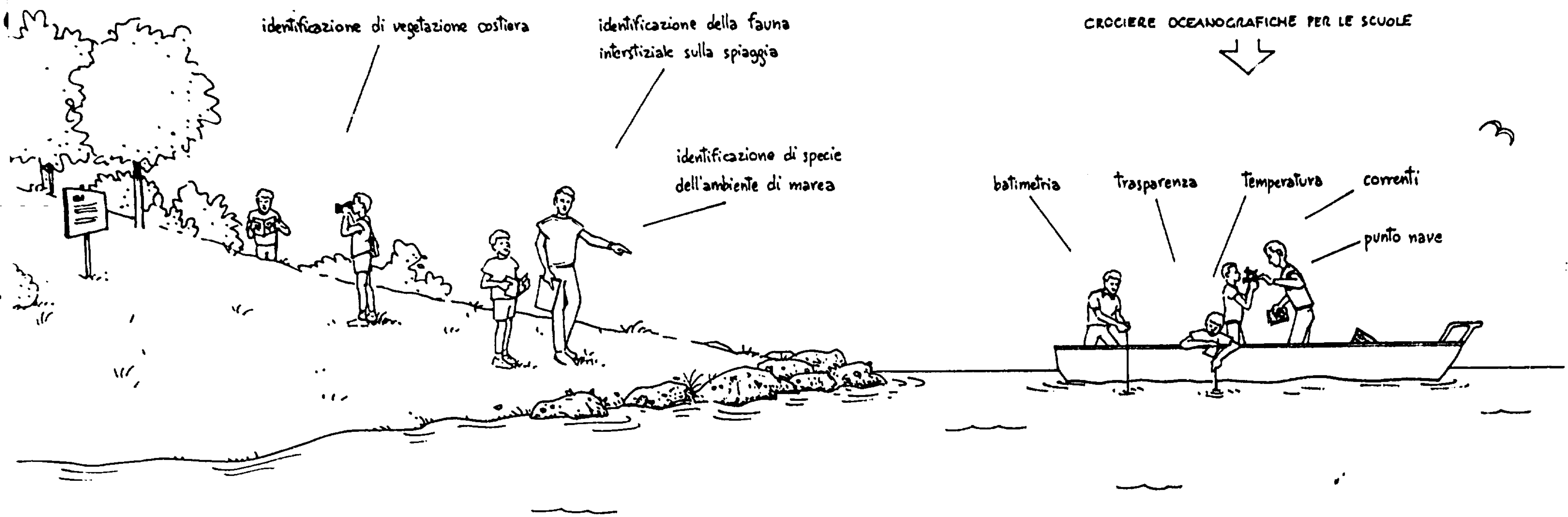
proiezioni di audiovisivi

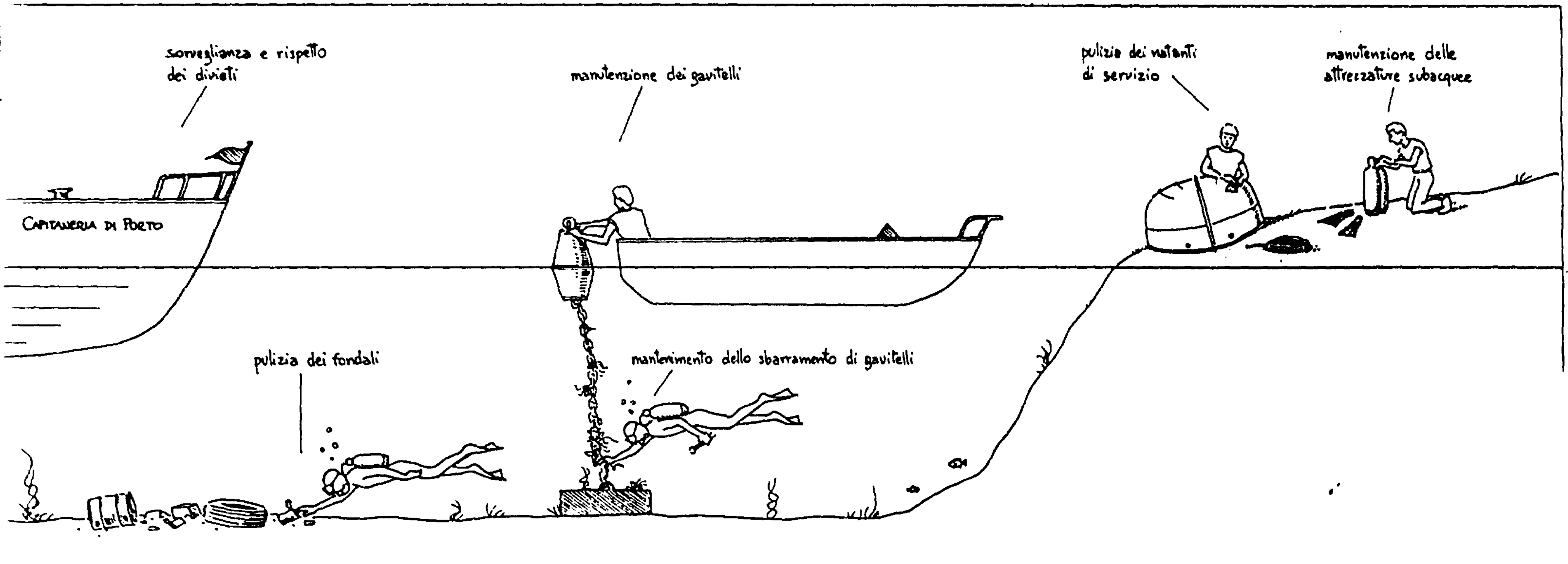


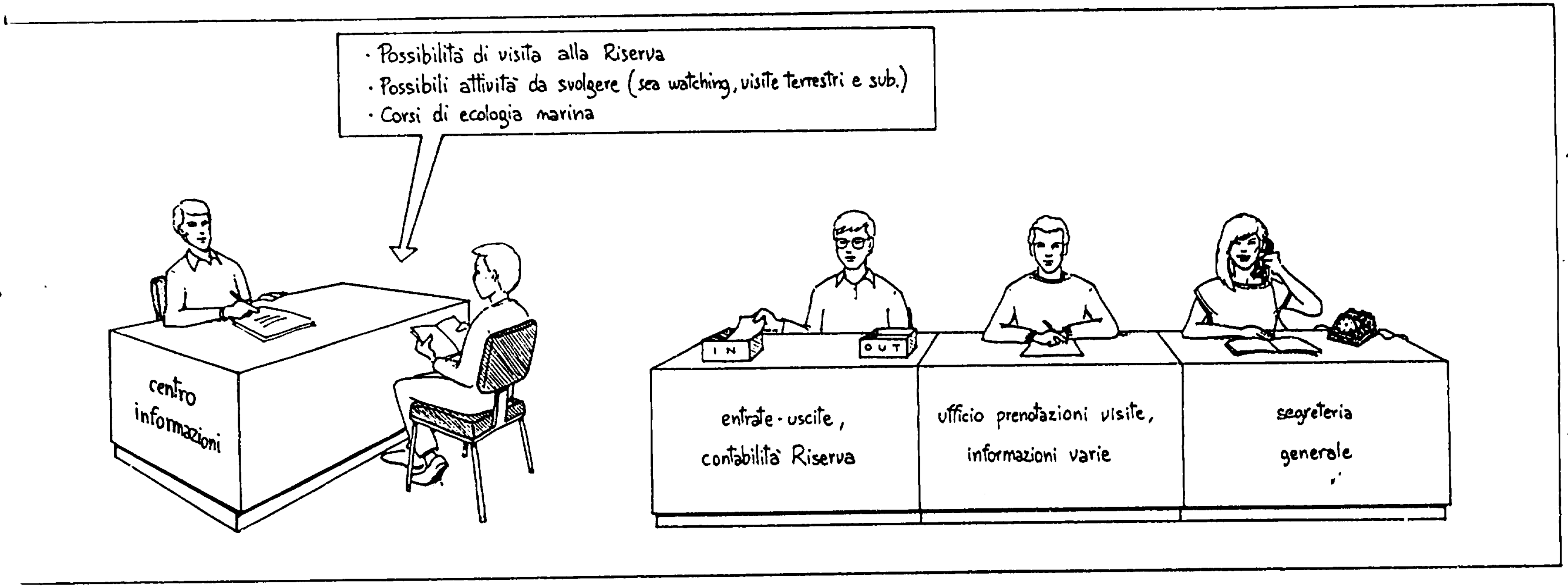
ricerche con dispense

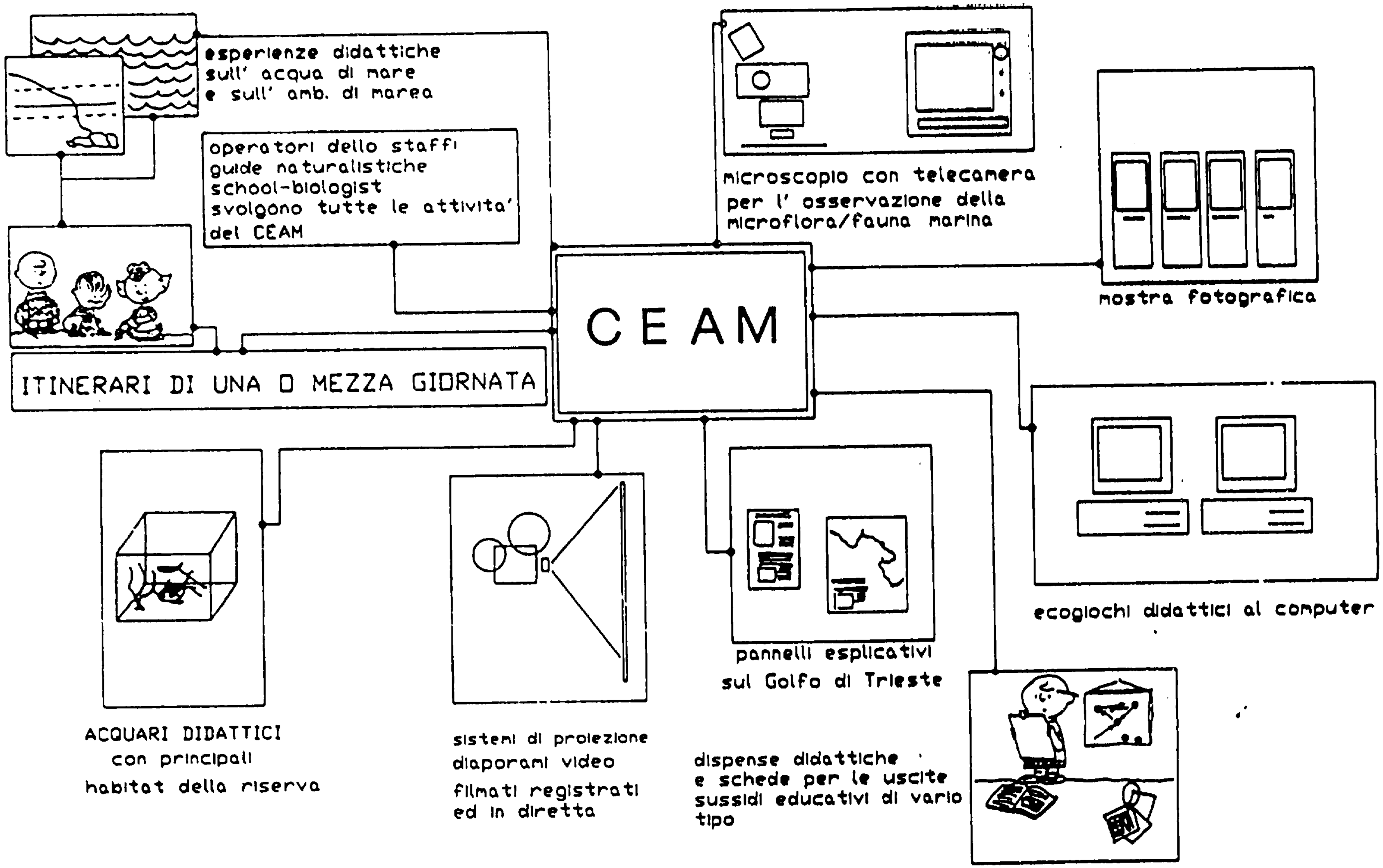

stazione elaborazione dati in continuo
controllo qualità delle acque
confronto con aree marine non protette
boa monitoraggio in continuo inquinamenti
O_2
idrocarburi
$PO_4^{=}$
NO_3^{-}
clorofilla
studi subacquei su fauna e flora protette
trasparenza
O_2
salinità
pH
Eh
T°
scogliera
prateria di fanerogame
studi su aree campione specie commerciali


visite terrestri autoguidate
attività terrestri guidate
sentiero natura di Miramare
visite in sea-watching guidate
visite sub con Guida Blu
3 m
8 m


identificazione di vegetazione costiera
identificazione della fauna interstiziale sulla spiaggia
identificazione di specie dell'ambiente di marea
CROCIERE OCEANOGRAFICHE PER LE SCUOLE
batimetria
trasparenza
temperatura
correnti
punto nave


sorveglianza e rispetto dei divieti
CAPITANERIA DI PORTO
manutenzione dei gavitelli
pulizie dei natanti di servizio
manutenzione delle attrezzature subacquee
pulizia dei fondali
mantenimento dello sbarramento di gavitelli


· Possibilità di visita alla Riserva
· Possibili attività da svolgere (sea watching, visite terrestri e sub.)
· Corsi di ecologia marina
centro informazioni
IN
OUT
entrate - uscite, contabilità Riserva
ufficio prenotazioni visite, informazioni varie
segreteria generale


esperienze didattiche
sull' acqua di mare
e sull' amb. di marea
operatori dello staff
guide naturalistiche
school-biologist
svolgono tutte le attivita'
del CEAM
ITINERARI DI UNA O MEZZA GIORNATA
CEAM
microscopio con telecamera
per l' osservazione della
microflora/fauna marina
mostra fotografica
ecogiochi didattici al computer
ACQUARI DIDATTICI
con principali
habitat della riserva
sistemi di proiezione
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filmati registrati
ed in diretta
pannelli esplicativi
sul Golfo di Trieste
dispense didattiche
e schede per le uscite
sussidi educativi di vario
tipo

IMPACT OF ACCELERATED SEA-LEVEL

RISE ON COASTAL ENVIRONMENTS

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International Conference on Climate and Man
Turin, Italy

January 1989

Abstract

A significant portion of the world's population lives within the coastal zone, with many buildings and facilities located at elevations less than 3 meters above mean sea level. These structures are presently subject to damage during major storms, and this hazard has grown increasingly serious as sea levels have risen during the twentieth century. Greenhouse-induced warming is expected to raise water levels at historically unprecedented rates, resulting in increased beach erosion and loss of coastal wetlands. There are three socioeconomic responses to accelerated sea-level rise in terms of human occupation: fortify the shore, retreat from the coast, and nourish the beach.

Introduction

Throughout geologic history sea level has fluctuated greatly. During the last Ice Age (approximately 18,000 years ago), sea level was as much as 100 meters below present levels. The earth at this time was about five degrees celsius colder than today. During warm interglacial periods, sea level has been at times several meters higher than present. Because of the historic relationship between climate and sea level position, it is expected that anthropogenic (human-induced) global warming could cause a significant rise in sea level. Warmer temperatures could expand ocean waters, melt glaciers, and eventually cause the disintegration of the West Antarctic ice sheet.

Climate can effect sea level position by heating and thereby expanding (or conversely cooling and contracting) surface sea water. This process can occur over relatively short periods of time. At present the mid-latitude mountain glaciers are still retreating. Although most of the glaciers have melted since the last Ice Age, there is still enough water in polar glaciers to raise sea level by more than 70 meters. Over longer periods of time, significant rises in sea level could be caused by disintegration of the West Antarctic ice sheet, which is marine-based and subject to temperature increases.

In the last century, surface temperatures have shown a gradual increase based on National Weather Service data, and tide gauges have recorded about a 30 centimeter rise along the U.S. Atlantic coast (Hicks et al, 1983). Some of this relative rise in sea level (relative to the land surface) can be explained by the natural compaction and subsidence of unconsolidated coastal sediments. However, part of this rise (at least 12 cm) can be attributed to thermal expansion of surface ocean waters and glacier recession, resulting from the observed warming of 0.4° C during the last century. Figure 1 shows the strong correlation between global temperature and sea-level rise.

Future Sea-Level Rise

Concern about a possible acceleration in the rate of sea-level rise stems from measurements showing that concentrations of carbon dioxide and other "greenhouse" gases produced by human activities are increasing in the atmosphere. Because these gases absorb (trap) long-wave radiation (heat) in the atmosphere, it is generally expected that the earth will warm substantially in the future. The National Academy of Sciences has convened two panels to review all the evidence and concluded that warming will take place.

There is no doubt that the concentration of greenhouse gases is increasing and will do so in the foreseeable future. However, considerable uncertainty exists regarding the amount of warming; it is generally agreed that a doubling of the greenhouse gases will raise the earth's average surface temperature by about 1° C if nothing else changed. It appears that most of the climatic factors will amplify the direct affects, but some negative feedbacks (such as increased cloud cover to offset part of the warming) cannot be ruled out. Nevertheless, two panels of the National Academy of Sciences (NAS) have concluded that a doubling of greenhouse gases will eventually induce a warming between 1.5° and 4.5° C.

Based on current trends, Revelle (NRC, 1983) estimated that sea level could rise by 70 cm (30 cm due to thermal expansion, the balance attributed to glacial melting) by the next century. There have been a range of estimates made by NAS, EPA, and various scientific investigators. The recent NAS Polar Research Board Report (1985) placed the total rise at between 50 and 200 cm by the year 2100. This range lies within the same values derived independently by EPA (Hoffman et al, 1986). The estimated magnitude and timing of increased sea-level rise are illustrated by Figure 2.

Effects of Sea-Level Rise

The principal effects of sea-level rise are increased flooding and wave-induced erosion. Salt-water intrusion can also be a problem in some areas, particularly affecting surface waters.

1. Flooding and Submergence

A rise in sea level represents a raising of water base level. Therefore, storm waves and surges can reach higher and further inland. This can result in accelerated beach erosion as explained later, and major flooding will occur more often. For example, "100-year" storms can occur in the future on a 15-20 year averaged basis by virtue of higher base levels when considering frequency-magnitude relationships of coastal flooding (Leatherman, 1983).

The most significant impact of higher sea levels will be the submergence of coastal wetlands. Intertidal salt marshes can adapt only to relatively moderate rates of sea level rise; rapid increases in sea level can literally drown these wetlands, converting them to shallow bodies of open water. It is worth noting that the present U.S. tidal marshes postdate the previous maximum rate of sea level rise during the Holocene (since the last Ice Age), when sea level rose approximately one meter per century (1 cm/year).

Much of the Louisiana coastal zone is experiencing a rapid relative rise in sea level (up to 1 cm/year) largely due to human-induced subsidence. Without adequate supplies of sediment to raise the elevation of the marsh surface, these wetland plants become water-logged and eventually die. Presently, Louisiana is losing four acres of marsh per day, and entire parishes (counties) will be under water within the next 100 years (NRC, 1987). During periods of only gradual sea-level rise, plant-generated (organic) sediment and inorganic materials from rivers, uplands, and the sea could maintain the marsh surface plain relative to sea level positions. However, the Louisiana marshes dramatically illustrate the problem of rapid water level changes, and can serve as useful analogs of what will happen elsewhere along the world's coastline with accelerated sea-level rise.

A one-meter rise in sea level could drown most of the coastal wetlands without necessarily creating new salt marshes inland. Even in natural areas, marshes will often contract because of the sloping nature of the land above the marsh plain (Figure 3). Where marshes are backed by urbanized areas, such as along much of the Long Island, New York coast for example, these habitats will be squeezed out of existence with future sea-level rise.

2. Coastal Erosion

Sea level is one of the principal determinants of shoreline position. There are several reasons why sea-level rise would induce beach erosion or accelerate on-going shore retreat: (1) waves can get closer to shore before dissipating their energy by breaking, (2) deeper water decreases wave refraction and thus increases the capacity for longshore transport, and

(3) with a higher water level, the wave and current erosion processes are acting further up the beach profile, causing a readjustment of that profile.

Most sandy shorelines are presently eroding on a worldwide basis (Bird, 1985). Historical records indicate the prevalence of shore retreat during at least the past century. The National Shoreline Study by the U.S. Army Corps of Engineers (1971) was the first overall appraisal of shore erosion problems in the continental United States. This study showed that 43 percent of the shoreline is undergoing significant erosion, excluding Alaska. In fact, this report indicates that most all of the U.S. ocean shoreline is undergoing erosion (excluding hard-rock coasts). Accretion is restricted to coastal areas where locally excess sediment is supplied by river sources or where the land is being elevated by tectonic (earthquake or glacial rebound) activity.

There are several different approaches that can be used to project new shorelines. Slope is the controlling variable, such that gently-sloping shores will undergo a much broader area of inundation for a given sea-level rise compared to steep-sloped areas. This is the preferred methodology to apply to immobile (rocky or armored) coasts or for sheltered coasts, such as small bays and estuaries.

The other approaches that have been employed to date are largely based on the erosional potential of sea-level rise (Leatherman, 1986a): (1) extrapolation of historical trend, (2) Bruun Rule, (3) sediment budget analysis, and (4) the dynamic equilibrium model. These methodologies, including applications and limitations, are discussed in a recent National Academy of Sciences (1987) report. Case studies along the U.S. coast yielded a comparable range of rates of shore retreat as predicted by the different approaches. A severe limitation to our forecasting future erosion rates is lack of good quantitative data on historical rates of shore retreat for much of the world's coastline.

For open ocean sandy beaches, at least a doubling and perhaps a five-fold increase in erosion rates can be forecast, depending upon the realized rates of accelerated sea-level rise. Many urbanized beaches are already critically narrow and continuing to erode, and accelerated sea-level rise will exacerbate an already serious problem (Leatherman, 1986b). Presently many U.S. recreational beaches are being nourished (e.g., Miami Beach, Florida, 1980s, $65 million) or will be nourished in the near future (e.g., Ocean City, Maryland, 1987, $30 million, first cost). More beaches will have to be replenished in the future and more often in order to maintain their recreational quality and provide storm protection for the landward-flanking coastal development.

Responses

A dominant and growing proportion of the world's population, facilities and development are located on coasts in sensitive balance with local sea levels. Even the lower estimates of accelerated sea-level rise will place many of the world's coastal cities in jeopardy in the coming decades. The low-lying coastal fringe is subject to catastrophic events of flooding. For example, the 1970 cyclonic flooding that killed over 300,000 people in Bangladesh will become a more frequent occurrence in the future as sea levels rise and the third world population continues to explode.

An accelerated rise in relative sea level will force people who live on the coasts to make a number of important decisions. The choice of a response strategy will depend upon several factors, including environmental, economic, and social factors (NRC, 1987).

There are essentially three possible responses: (1) fortify the shore, (2) retreat from the coast, and (3) nourish the beach. Armoring the shore with such coastal engineering structures as seawalls, breakwaters, and bulkheads is very expensive, and often compromises the resources (loss of a recreational beach). Planned retreat is the best option for sparsely developed areas. Beach nourishment is the most attractive alternative where highly urbanized areas must be protected and high value is placed on maintaining a recreational beach. Selection of the appropriate response will be site-specific on the basis of existing conditions. The costs and benefits of stabilization vs. retreat must be carefully considered as the cost in either case is likely to be quite high.

Summary and Conclusions

1. There appears to be a strong co-relationship between earth warming and sea-level rise. During the past century, sea level has risen about one foot (30 cm) of which about one-half can be attributed to global causes, concurrent with warming of the earth's surface by 0.4° C. The chief uncertainty lies in how rapidly the polar glaciers may melt.
2. Several groups have projected sea-level rise, notably the National Academy of Sciences (NAS) and the Environmental Protection Agency (EPA). Two panels of NAS have been convened and concluded that sea level will increase by 70 cm by 2100 (1983 Revelle report) with the most recent estimates by the NAS Polar Research Board (1985) ranging from 50 to 200

cm. These ranges are comparable to the most recent (1986) EPA projections of 57-368 cm.

3. Wetlands will be much affected by accelerated sea-level rise, resulting in significant losses. Wetlands can shift inland, but their area will drastically shrink due to the sloping nature of the flanking mainland. Where urbanized, wetlands will be essentially squeezed out of existence. Clearly, some areas will lose more marsh than others, depending upon topographic conditions and anthropogenic controls. It is doubtful if people will be willing to abandon urbanized areas to allow for wetlands invasion concurrent with sea-level rise.

4. Sea-level rise will promote increased coastal erosion. Already approximately 70% of the world's sandy coastlines are eroding, and accelerated sea-level rise will only exacerbate this critical problem. Rates of shore erosion will probably at least double and may increase five-fold based on the realized rate of water level changes. As a rule of thumb, a 30 cm rise in sea level will result in 30+ meters of erosion along the U.S. Atlantic coast applying the Bruun Rule. This means that most recreational beaches would be lost since so many are already critically narrow. Artificial nourishment is being used to restore some U.S. beaches, but the costs are high. Accelerated sea-level rise will increase the quantity and frequency of beach restoration projects.

5. It is certain that these potential problems will only worsen in the near future. Within the next 40-50 years, sea level will probably have risen by about 30 cm, resulting in major impacts to coastal environments. Rather than triggering dramatic change, sea-level rise will promote gradual erosion and invariably increase the vulnerability of human

development as well as culminate in significant losses of wetlands. These impacts are perhaps more insidious than the short-lived, dramatic storm-induced damages to coastal areas.

6. There are three general responses to accelerated sea-level rise: fortify, retreat, or nourish. The proper response will be based on site-specific information on environmental and socioeconomic conditions on a community or coastal sector basis. In any case, the long-term costs are likely to be high along the world's low-lying and sedimentary (erodible) coasts.

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