Draft Final Report R&D Project No. 386

REHABILITATION OF COASTAL STRUCTURES
Phase I

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CONTENTS LIST Page

1National Rivers Authority

Research and Development Project No. 386

REHABILITATION OF COASTAL STRUCTURES

Draft Final Report - Phase I

1.0 PROJECT OBJECTIVES AND BACKGROUND

1.1 Project Objectives

The overall objective of the project is to develop guidelines for the rehabilitation of existing NRA coastal structures. The project is to be carried out in two phases with the specific objectives of Phase I being as follows:-

a) To assess the available literature, including these publications, CIRIA Technical Note 125, "Sea Walls - a survey of design and performance", CIRIA publications "Sea Wall Design Guidelines" and "Maintenance and Rehabilitation of Old Water Front Walls", the NRA Sea Wall Survey and the Anglian Sea Defence Management Study.

b) To identify major faults threatening failure of sea defence structures.

c) To identify basic method of solutions to each type of sea defence structure.

d) To produce from the literature an assessment of the scope required from the project and the subject areas it should cover where not covered adequately in the available literature.

e) To compile a contents list for the proposed Guide to the rehabilitation of structures, relating to the needs of NRA and the information published already (guide should in this case reference such work, subject to agreement of Project Leader).

f) To assist the Project Leader in the production of the terms of reference for Phase II and shortlist potential contractors.

Phase II

To be assessed after the Project definition study.

1.2 Background

The purpose of the project is to produce a guide to the rehabilitation work on coastal defence structures undertaken by the NRA. This will involve a review of the literature, in particular some major recent works, and the assessment of the types of sea

defence structure maintained by NRA. The guide to rehabilitation of structures will be aimed at the graduate engineer level, but not necessarily with coastal defence experience. The purpose in phasing the project is that much of this work may have already been published and will not require extensive review. In such cases, the scope of the project will be reduced and good referencing of that work may cover the needs of NRA. This will ensure therefore that the project is well planned and will ensure good value for money.

Phase II will be put to competitive tender.

1.3 Method

The objective in carrying out the study in two phases was to ensure that due account was taken of the contents of a number of major new publications related to the subject matter which had either just been published or were forecast to be published during the first phase work, and would therefore have a major bearing on the recommendations for the Phase II work.

1.4 Definitions

For the purpose of this study the following definitions, which are in line with general practice, were adopted:-

Coastal Structures:- To include both seawalls and revetments (as defined below). This definition is considered to apply to structures which lie within the Section 4 boundaries of the Coast Protection Act 1949, consequently estuarial flood banks are not covered by this study. This is in agreement with the boundaries adopted for the NRA Seawall Survey and the Anglian Region Sea Defence Management Study.

Seawall:- A shoreline structure whose primary purpose is either protection against erosion or the alleviation of flooding, or a combination of both, in which wave action is the dominant design consideration.

Revetment:- A cladding of stone, concrete or other material to stabilize and protect shorelines, embankments or shoreline structures against the action of waves and currents. It may form part of a seawall structure.

Rehabilitation:- There is an important distinction to be made in this definition between Renovation, which relates to major works to restore a wall to its original state and standard and Upgrading, which takes account of a change of function and/or an increase in the standard of the wall. Such works are usually classified as "Capital Works".

Maintenance:- Routine inspection, structural evaluation and small scale works to repair parts of a wall. Such works usually being classified as "Revenue Works" and therefore fall outside the definition of rehabilitation.

2.0 LITERATURE REVIEW

There is no single publication which deals solely with the specific subject of the rehabilitation of coastal structures but there are now three principal documents which cover the subject but from differing standpoints. It should also be pointed out that two of the books, Seawall Design and Old Waterfront Walls were published after this project was started, whilst the Rock Manual only became available during the first month of the project.

(a) "Seawall Design" by R.S.Thomas and B. Hall., published by CIRIA/Butterworth Heinemann. 1992.

(b) "Manual on the use of rock in coastal and shoreline engineering" CIRIA Special Publication 83 and CUR Report 154. 1991.

(c) "Old Waterfront Walls - Management, maintenance and rehabilitation" by R.N.Bray and P.F.B.Tatham, published on behalf of CIRIA by E & FN Spon. 1992.

Additional publications reviewed included:-

(i) CIRIA Technical Note 124 -"Coastal Revetments"

(ii) CIRIA Technical Note 125 -"Seawalls - Survey of design and performance"

(iii) CIRIA/HR "Seawall Literature Review" by N.W.H. Allsop. Hydraulics Research Limited, Wallingford, Report No. EX. 1490. September 1986.

(iv) "Shore Protection Manual" Vol.1-2. Coastal Engineering Research Centre, US Government Printing Office, Washington, D.C. 4th. edition.

The study also benefitted from the Author's involvement with Posford Duvivier in another NRA R&D Project No. 382 - "Armourstone Foundations".

2.1 Literature Review - Method

Given the overall objectives of the study, it was decided that the method to be adopted for the literature review should be centred around the basic requirements of a future NRA Guideline document. Having accepted this premise the following topics then had to be considered:-

- What sort of guideline is required bythe NRA ?
- Does the information already exist ?
- If so, does it cover the specific requirements or are there gaps ?
- Is it dispersed among a number of separate documents ?
- If it is, is there a need/justification for bringing it together into a single NRA document ?

The basic subject areas which would be considered necessary for an NRA guideline were therefore established and used to judge the adequacy of the three principal publications.

2.2 NRA Guideline Requirements

There are a number of judgements to be made when detemining the content of a guideline on the rehabilitation of coastal structures. Firstly, and very importantly, the level of readership. This has been defined in the terms of reference as " the graduate engineer level but not necessarily with coastal engineering experience."

Secondly, the range of subject areas covered by the project is considerable, and no one publication could ever hope to cater for all of them, particularly where a high level of specialist knowledge and experience is involved. In such instances the guideline should seek to alert the reader to the need for specialist advice.

Thirdly, the whole question of the initiation of rehabilitation works presupposes a history of inspection, maintenance, repair and monitoring. This in turn may involve a recognition of the requirements, both short and long term, derived from Regional or District strategy or coastal management studies.

In the light of the above the suggested main subject headings of such a guideline are as follows:-

a) Types of structure.
b) Maintenance and repair.
c) Inspection and monitoring.
d) Failure modes.
e) Data collection and investigations.
f) Coastal processes.
g) Assessment of condition of structure.
h) Design criteria.
i) Design, both outline and detailed.
j) Materials.
k) Economic appraisal.
l) Environmental assessment.
m) Specifications.
n) Physical and mathematical modelling.

Each of the three principal publications have been reviewed in the light of the above headings taking account of:-

- The level of readership.
- The depth of coverage in terms of technology and good engineering practice.
- The extent of shortfalls or gaps in detail and .
- Adequate exposure of limitations in technology.

3.0 DETAILED ASSESSMENT

3.1 Approach adopted in publications

The approach adopted in the presentation of material in both the Seawall Design and Rock Manual is based on logic diagrams of typical design office practice and procedures but also takes account of the need for random access for reference on individual subjects. The Seawall Design guide is particularly useful in that the basic design logic diagram is repeated at the begining of each section with the subject matter of the particular section highlighted. This has the double benefit of not only identifying the subject but also showing its place in the design process and acts, furthermore, as a reminder of other essential aspects which might otherwise be overlooked.

All three books emphasize the need for a logical and systematic approach centred aound an initial and fundamental requirement to establish the "nature and scale of the problem".

Whilst the Old Waterfront Walls publication is specifically concerned with the subject of "Maintenance and rehabilitation", the other two appear to deal more with "new works" but having said this it is a fact that the procedures and practices are to a great extent identical irrespective of whether it be new work or rehabilitation. There are however some important differences and these are highlighted and are discussed later where appropriate.

3.2 Structure Type

The range of structure types covered by the three publications is as follows:-

(A) Seawall Design (see also Figure 1)

- Seawalls, both vertical and sloping
- Armoured slopes - porous
- Stepped slopes - non-porous
- Smooth slopes - non-porous
- Gravity structures -proous and non-porous
- R.C.Retaining walls - non-porous
- Sheet piling
- Cribwork and breastwork - timber with/without rock hearting
- Groynes - timber

(B) Manual on the use of rock in coastal and shoreline engineering

- Breakwaters
- Seawalls, groynes and shoreline protection structures
- Dam face protection
- Rock-fill offshore engineering

(C) Old Waterfront Walls

- Quays, dock and lock walls
- Vertical breakwaters
- Seawalls for coastal defence (vertical)
- Retaining walls and flood defences
- Skin walls
- Bridge piers and abutments

The range of structures covered is therefore very comprehensive and importantly includes old vertical structures dating back to the last century, their methods of construction and materials.

In terms of rehabilitation work on sea defences the Seawall Design guide covers the widest range of types. However, given the current trend towards the use of rock then there is important and useful coverage in the Rock Manual. The Old Waterfront Walls is more directed towards the vertical or battered type of structure but has a relevance as it covers both masonry and brick construction.

The extent of overlap is minimal and each publication recognises and refers to the others. No one document comprehensively covers all structure types.

3.3 Maintenance and Repair

This subject heading has been suggested for inclusion in the NRA guideline because of the importance of a knowledge and understanding of the extent and methods used in maintenance and repair work when evaluating future options including rehabilitation.

There is a wide range of issues involved with regard to maintenance and repair in the context of rehabilitation such as:-

- The life of the structure and its standard of service.
- The evaluation and decision as to whether further maintenance and repair is cost effective.
- The extent and type of work which has been carried out in the past and its effectiveness.
- Changing conditions such as sea level rise or increasing erosion.
- Restrictions on materials due to environmental considerations (ie. hardwoods etc)
- Maintenance considerations in the design process.

The most comprehensive statement on maintenance and repair is contained in Old Waterfront Walls Chapter 3 "Management of maintenance and rehabilitation" and gives much useful information particularly on a more structured approach to integrating maintenance and inspection procedures. There are useful logic diagrams showing the various stages in the above process which also includes rehabilitation works.

It also emphasizes the factors leading up to what is designated as the "critical point of disrepair" which is defined as the point at which the onset of progressive failure occurs.

3.4 Inspection and Monitoring

Chapter 4 of Old Waterfront Walls "Inspection and monitoring" deals very adequately with this subject covering such items as, objectives of inspection programmes, procedures for implementing programmes, types of inspection, both above and below water level and recommendations for the proper recording of the results. Whilst the methods and techniques are directed more towards dock walls and similar structures many of the principles are applicable to coastal structures.

The Seawall Design guide and the Rock Manual deal with this subject in rather broader terms as an essential element of coastal management or data required for scheme design. As such they tend to cover inspection, not only of the structures but also offshore, the coastal zone, backshore area, coastal slope and hinterland.

All three books tend to make a distinction between "inspection" and "investigation" although it is admitted that the demarcation line is frequently vague in practice.

3.5 Failure Modes

All three books cover this subject and the matter is dealt with in more detail later in this report.

3.6 Data Collection and Investigations

There is a very adequate and comprehensive discussion of this topic in all three books. However in terms of coastal structures the Seawall Design guide, Chapter 4, "Data Collection, Analysis and Interpretation" is much the better for the requirements of this present project, in that it deals with the recording and /or forecasting of winds, waves, tides, water level, surges, currents, beach movement and coastal processess, geotechnical investigations and hydrographic surveys. Most importantly it discussess data validation, analysis and interpretation.

3.7 Coastal Processes

Because of the very specialised and complex technical nature of this subject , none of the three principal books reviewed go into the matter in great detail. The Shore Protection Manual however does go into considerable detail on all aspects of the subject, but it has to be said that many new advances have been made since its publication in 1984.

Whilst there is much in all the books which will be of value to the young graduate engineer this is quite definitely an area where very specialist advice is essential and particularly if physical or hydraulic modelling is involved.

3.8 Assessment of Condition of Structure

Of all the topics covered in the literature this is the one subject area where there is universal agreement that "there is no substitute for experience and engineering judgement".

Nevertheless the most practical and detailed exposition is to be found in Old Waterfront Walls, Chapter 6, "Structural appraisal of a wall". The introduction to the chapter starts with the statement that "Waterfront walls are notoriously difficult to assess, both in terms of their stability and in their rate of deterioration" and goes on to warn that apparent abnormalities may be relatively harmless while the factors which are crucial may go undetected. It emphasizes the need for a diagnostic approach based on a list of identified defects set against possible causes, an understanding of the possible modes of failure and the need for great care in the calculation of wall stability and interpretation of the results.

The only important ommission in this chapter is the absence of any reference to the use of the "Fault Tree" approach in achieving an understanding of the many potential causes of failure. This approach is, however, dealt with in Seawall Design and the Rock Manual and is discussed later in this report under the heading "Modes of Failure".

3.9 Design Criteria

This subject is set out in great detail in all three books. The Rock Manual and Seawall Design are obviously the most appropriate publications in the context of this study and contain useful discussion on design philosophy as it relates to use of "deterministic" and "probabilistic" methods.

3.10 Design

Overall project planning is dealt with in all three books and includes topics such as preliminary cost/economic assessment, functional requirements and initial evaluation of options. If there is a criticism to be made here, it is that more guidance could be given, particularly to engineers with limited experience of coastal works, on some of the important differences between "new works" and "rehabilitation". One of the main issues here, for instance, is that the engineer starts his work from a different baseline where certain fundamental parameters such as wall location and alignment are already fixed. Furthermore the coastline is no longer natural but artificial but nevertheless represents an asset, the value of which he must seek to maximize. This will most certainly pose very different problems in design, not the least of which may be the recognition that the existing wall, by present day standards does not represent best practice or has been the cause of problems on adjacent coastlines

With regard to design, both outline and detailed, the Seawall Design publication is the most comprehensive. It not only considers the plan shape and location of the structure but deals with the cross section , firstly as a whole and then breaks it down into its principal elements, ie., the toe, front slope, crest including decking and the back face. There are also sections on hydraulic performance, design of slope protection, structural

considerations, design for construction and maintenance and an immensely useful section on detailing of the various elements.

If one adds to this the exceptionally detailed information on the use and design of rock structures in the Rock Manual then the engineer has virtually a complete "state-of-the-art" available to him.

The recommendations in these two books are equally applicable to both new and rehabilitation work.

3.11 Materials

The most comprehensive and up to date coverage of materials is contained in Seawall Design and this, together with the very detailed information on all aspects of rock in the Rock Manual very adequately covers the subject.

Rehabilitation work can however require an understanding of materials used in the 18th 19th and early 20th. century and this is dealt with in Chapter 1 of Old Waterfront Walls.

3.12 Economic Appraisal

Economic appraisal and Benefit Cost Assessment in terms of UK practice and therefore NRA requirements is best set out in the Seawall Design publication. The Rock Manual takes a broader review as it includes for Dutch practice.

3.13 Environmental Assessment

United Kingdom practice on Environmental Assessment is very thoroughly described in Seawall Design and covers coastal processes, flora and fauna, human sensory, social and socio-economics, geology, archaeology, history and pollution.

The Rock Manual also contains a similarly detailed description of the subject.

3.14 Specifications

Seawall Design contains no "model" specifications as such, but the very detailed sections on "materials" and "detailing" contain a wealth of practical information which would be of considerable assistance in the preparation of specifications.

The Rock Manual on the other hand does contain "model" specifications for rock which are, in many cases, greatly in advance of present day practice. They seek to set new standards for this type of work and are therefore to be recommended.

No model specifications are given in Old Waterfront Walls but references are supplied for specialist applications such as sprayed concrete.

3.15 Hydraulic Modelling

The most detailed description of both physical and mathemetical modelling as it applies to coastal works is contained in Seawall Design and the Rock Manual. Both publications make clear the limitations of particular methods and stress the need for expert specialist advice. There is sufficient information for the graduate engineer to develop an initial understanding of this complex subject and an adequate warning of the difficulties in the interpretation of results. It has to be remembered, however, that this is one subject area where there are continual advances being made as a result of basic research worldwide, consequently it is the one section in each book which is certain to be out of date in a relatively short time.

4.0 MAJOR FAULTS THREATENING STRUCTURAL FAILURE

4.1 Major Faults

The terms of reference for this project required a statement on the "Identification of major faults threatening failure of sea defence structures". The Seawall Design publication deals with this subject in considerable detail in Sections 3 and 5, but quite specifically does not attempt to identify all possible types of damage or failure. Quite simply the reason for this is the very great variation in the types of seawall which exist in this country, from porous to non-porous, sloping to vertical, singly or in combination and the variety of materials employed even within a single structure. It does however list the results of a questionnaire carried out in 1984/5 (CIRIA Technical Note 125) on the most frequent types of damage to seawalls reported by 237 Authorities in the UK and which is reproduced below.

Damage reported to seawall	No of occurrences	% of seawalls reported
Erosion of toe	63	12.3
Partial crest failure	26	5.1
Removal of revetment armour	19	3.7
Collapse/breach	16	3.1
Abrasion	16	3.0
Wash out of fill material behind seawall	10	1.9
Concrete disintegration	9	1.7
Structure member failure	5	1.0
Landslip	5	1.0
Damage to promenade/decking	4	0.8
Corrosion	3	0.6
Outflanking	3	0.6
Uplifting of armour	3	0.6
Settlement	2	0.4
Spalling of concrete	2	0.4
Concrete cracking	2	0.4
Total	188	36.6

Further details or information on seawall damage or failure was sought from the report on the NRA Sea Defence Survey 1990/1991 - "Survey Report Phase 1, Phase 2 and Phase 3, January 1991". In terms of the requirements of this present project, ie, details of types of damage and/or failure, the report contained no useful information. It must however be said that it was not the intention of the survey to record that degree of detail. Providing the conclusion of the present study is to proceed with a second phase it may be appropriate to consider whether or not to include a further in-depth survey of Regional archives to assemble and analyse whatever data may be available in this topic.

Reverting to the results of the CIRIA questionnaire

The report (CIRIA Technical Note 125) commented further that "as might be expected the commonest type of damage reported was erosion of the toe, but collapse/breach and washout of fill material are equally serious and could be caused initially by toe erosion. The instance of partial crest failure is also high, but it has not been possible to determine any common factor in the cases reported".

The report also goes on to state that "more vertical walls than any other shape have been reported with damage (35%) but note also that 36% of the total sample of walls were vertical. Within remarkably close limits the number of cases of damage is in direct proportion to the number of examples reported for each wall shape, suggesting that no one shape of wall is more susceptible to damage than any other."

Whilst the table above does, to some extent, itemize types of damage as singular events in reality the overall damage can include, or be the result of, many of the individual items acting in combination or in sequence.

For instance, "wash out of fill material beneath a seawall" can result from "concrete disintegration" of the elements of the wall due to "abrasion" from beach material.

"Abrasion" can also reduce the thickness of the steel sheet piling forming the toe of the wall leading to extensive holes and "loss of fill material".

Finally, "erosion of the toe" which is the failure to maintain adequate levels of beach in front of the wall requires an in-depth study of coastal processes if the true cause of the problem is to be established. The source of the problem may be works carried out on shorelines remote from the site in question causing a significant reduction in littoral transport of beach material. It is this interactive mechanism which has lead to the development of the "fault tree" approach to identify the true nature and causes of damage or failure to coastal structures.

4.2 Fault Tree Diagrams

The system was developed, both in the UK and Holland in the late 1970's, to investigate the failures which had occurred to a number of major rubble mound breakwaters throughout the world. In the process it not only gave a fresh insight into the understanding

of how these structures functioned but very significantly exposed the extent of limitations in technology.

A fault tree diagram is essentially a "cause and effect" diagram where all the possible interactive reasons or "causes" of a particular "effect" are set down and examined. If , for instance, the particular "effect" is, say excessive flow over the wall (overtopping) this can be caused by either a) the crest level being low, b) inadequate hydraulic performance (run-up too great) or, c) environmental loading too severe. Each of these "causes" then in turn become "effects" and further "causes" are identified for each. Taking a) "crest level low"-there are a number of causes which can account for this, such as damage to the crest, erosion of the core, regional subsidence, settlement of the crest or geotechnical instability. The process is then continued for each new item until the engineer is satisfied that he has exhausted all possibilities and has developed a better understanding of the situation and that no important "causes" have been missed.

In constructing such diagrams it is important to put down all possible cause and effect situations even if, at first, they do not appear to be relevant to the particular problem being investigated. Subsequent stages in the development of the diagram may reveal an unexpected and significant situation which in turn may require a radically different solution than originally anticipated.

If, for instance, the real cause of the problem is determined as "loss of beach" and the source is remote from the site it may well be that rehabilitation works may not be appropriate and the engineer is forced to consider the need for a major review of the coastal strategy.

Two typical examples of "fault tree" diagrams are included (Figs 2 & 3) which have been taken from Seawall Design, one for the case described above ie, "flow over the wall" and the other for "loss of beach" (erosion).

There are many additional benefits to be obtained from the "fault tree" approach such as:-

a) A better awareness of the data required for the development of "design criteria"
b) Instigation of relevant site investigations
c) The development of appropriate design criteria
d) A design which takes better account of previous shortcomings
d) Recognises and takes account of limitations in technology
e) Incorporates and evaluates the importance of changed conditions such as "sea level rise".

There is one other issue which, to date, has not been included in the fault tree approach to failure mechanisms and that is "Environmental damage". I can see no reason why this should not be included but the details would require considerable thought and as such must lie outside the scope of this first phase of the project. It is perhaps worth adding at this juncture that the extent to which environmental issues are influencing the design of all coastal works strengthens the case for their inclusion.

Finally, it has to be admitted that the preparation of fault trees does require an above average appreciation, understanding and experience of coastal engineering. However, providing that such experience is available within a particular design group then the "fault tree" approach can be of considerable benefit to the relatively inexperienced engineer as a learning tool.

5.0 BASIC SOLUTIONS FOR REHABILITATION WORKS

5.1 General

Right at the outset and particularly in the light of what has been said in the previous section on modes of failure it is profoundly wrong to give the impression that there are "Typical or basic solutions" for rehabilitation works. An example may serve to demonstrate the point.

In the past a common solution to the problem of erosion and undermining of the toe of a vertical sea wall, be it concrete or masonry, was to construct a concrete apron which in turn incorporated a steel sheet piled toe. Whilst this solution, which was eminently practical, solved the immediate problem and secured the foundations of the wall, it frequently did not either recognise the real problem or deal with it and in many cases did little more than buy time. Erosion would continue and there have been cases where yet another similar construction was added at a later date to combat the continuing erosion.

Furthermore by failing to deal with the underlying basic problem of erosion the beach foreshore levels would continue to drop and in the process result in greater depths of water at the structure thus allowing increased wave action, increased forces on the wall and increased overtopping. It is recognised that such options may provide short term solutions and in the process meet inevitable cost constraints but the long term effects and their consequences, which may be profound, must be evaluated at the same time. The fault tree approach is invaluable in such a situation and if implemented would almost certainly have identified a more appropriate solution to the one described above. Importantly it may indicate the need for a major review of "Coastal strategy" for a much greater length of coastline than was originally contemplated.

5.2 Renovation or Upgrading

When considering and evaluating options for rehabilitation work consideration will be given to two basic options, either "renovation" (restoration to its original state) or "upgrading" the structure.

In either case, a particularly important aspect is the age of the structure bearing in mind that there are in the UK a considerable number of seawalls dating from the second half of the 19th century (some of which are "listed structures"). The benefits to be derived from obtaining original drawings of these structures, if at all possible, cannot be stressed too highly and the sometimes considerable effort involved will be amply repaid. Construction methods and materials employed differed greatly from present day practice and ignorance of these factors can lead to wholly inappropriate solutions or increased risk during subsequent

construction work. Much useful information on these particular aspects can be obtained from the CIRIA publication "Old Waterfront Walls".

In the absence of such historical information the engineer should proceed with considerable caution especially during the detailed inspection of the structure and any subsequent site investigations. It is frequently necessary, for instance, to "open up" the structure to obtain the required information as there are few "non destructive" methods available at present. In this regard the reader is again referred to the "Old Waterfront Walls" publication which contains much specialist advice on this subject.

Given the present necessity to take account of global warming and sea level rise there may well be little option but to upgrade the structure if its "standard" is to be maintained. This is most likely to manifest itself in the need to combat increased wave overtopping and/or increased wave forces on the structure.

The options here are many and various, from a redesign of the crest of the wall to more major works incorporating a linear rock mound toe berm or slope.

The selection and evaluation of options does however require a basic knowledge and understanding of waves and their interaction with structures and the coastline. Advances in technology, as a result of worldwide research, has greatly increased such an understanding to the extent that a major shift in thinking is taking place. Opportunities now exist to develop solutions which seek to absorb and dissipate the energy of waves within porous types of construction (the so called "soft" solutions) as opposed to the previous philosophy of explosive confrontation between waves and solid, vertical or steeply sloping impermeable structures (the "hard" solutions).

It is because of these changes which are taking place that it is unwise to put forward the idea that there may be "basic" or "typical" solutions to the problems associated with the rehabilitation of coastal structures. Furthermore, every coastal site has conditions specific to that location and structure alone and the nature and scale of the problems encountered are equally unique. The design solution must reflect that uniqueness and it is for this reason that no attempt has been made in this report to promote the acceptance of "typical" solutions.

6.0 SUMMARY AND CONCLUSIONS

This study has focused on the need or otherwise for the production of NRA Guidelines on the rehabilitation of coastal structures with particular reference to the following points:-

- What sort of guideline would be required by the NRA ?
- Does the information already exist ?
- If so, does it cover the specific requirements or are there gaps ?
- Is it dispersed among a number of separate documents ?
- If it is, is there a need/justification for bringing it together into a single NRA document?

Three major CIRIA publications dealing with the subject matter of this report , which were published soon after the commencement of the project, have been reviewed in detail together with another four existing publications, the results of the NRA Seawall Survey 1990 and the Anglian Region Sea Defence Management Study.

In the light of the questions above and the agreed projected contents of an NRA Guideline document the following conclusions are put forward:-

1. To all intents and purposes the information does exist and meets the requirements of the proposed guideline.
2. The information is dispersed amongst the three principal CIRIA publications. It should however be noted that, each of the documents concerned were part of an integrated research strategy within CIRIA to achieve state-of-the-art publications which met the expressed needs of its members which included the NRA. Furthermore, it was a condition of the terms of reference for these documents and their many authors, that the contents be directed towards a readership level of a graduate engineer with minimal experience of coastal engineering. They therefore also comply with the terms of reference for this present project.
3. Each book is a major work in its own right giving extensive coverage of the particular subject matter and it would not be practical to bring the contents together into one volume.
4. In the context of the rehabilitation of coastal structures the Seawall Design publication is the most comprehensive and relevant document with the Rock Manual and Old Waterfront Walls books supplying useful and additional specialist detail.
5. Given the above conclusions there would appear to be no justification for producing a major NRA guidance document and in the process duplicating all the work which has already been done. In any case such a document would have to run to more than one volume which, of course, exactly reflects the present situation.

7.0 RECOMMENDATIONS

Accepting that there appears to be no justification for the production of a separate NRA guideline there may however be a need for a somewhat simpler in-house Technical Note

which draws the attention of the graduate engineer to the content of the books and the extent to which they deal with mutually related subjects and the detail covered in each subject.

What is envisaged is a form of extended "aide memoir" based on selected key words and possibly diagrams to assist the reader in locating the subject of interest followd by a relatively brief summary of the coverage and recommendations as to which of the publications is most appropriate. This would not only ensure that the engineer was made aware of the existence of the books but also that important matters of detail are thoroughly examined and not overlooked. It could also provide warnings, in the case of "old structures" of the need to seek an understanding of earlier materials and methods of construction as set out in the Old Waterfront Walls publication.

Initial thinking suggests an approach based on the "design flow diagram" in Seawall Design (reproduced here as Figure No.4) with each topic expanded to include the required references to the relevant chapters and sections in each of the three publications. For instance, the topic heading "Materials, durability, maintenance, availability, etc." would direct the reader to Section 7 of Seawall Design, Chapter 3 of the Rock Manual and its Appendix 1 on Model Specifications for rock work, Appendix 2 on Standards for quarried rock, and Appendix 3 on Measurement of quarried rock. It would also refer to a number of sections in Old Waterfront Walls.

The title of the proposed document could well be "Rehabilitation of Coastal Structures - Design Guidelines" because that is exactly what it would be. Assuming that it is based on the design flow diagram mentioned above then, as there are 28 topic headings and further assuming no more than two pages per heading, the resulting document would run to some 60 pages if one allows for contents lists, index etc. This would appear to be reasonable.

Experience suggests that such a document would be of value in the day to day working of a design office and it is therefore recommended that there should be a second phase to this project and that it be directed to the production of a Guideline document generally on the lines suggested above.

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Consulting Engineer
Research Contractor.

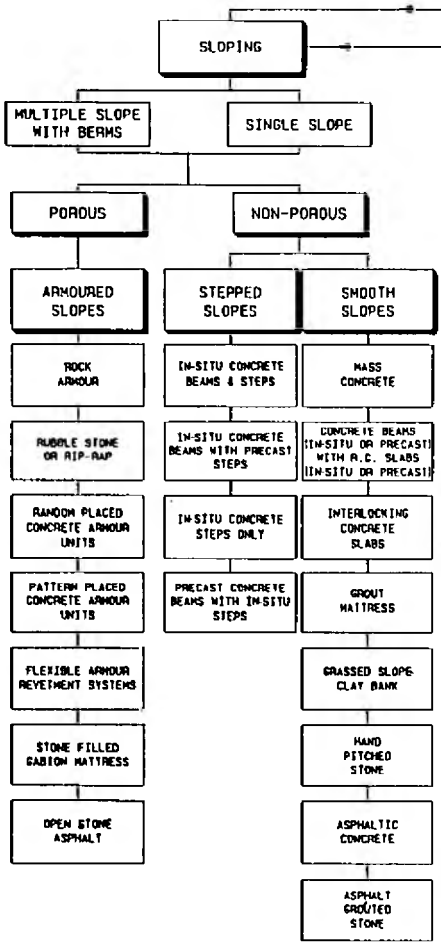
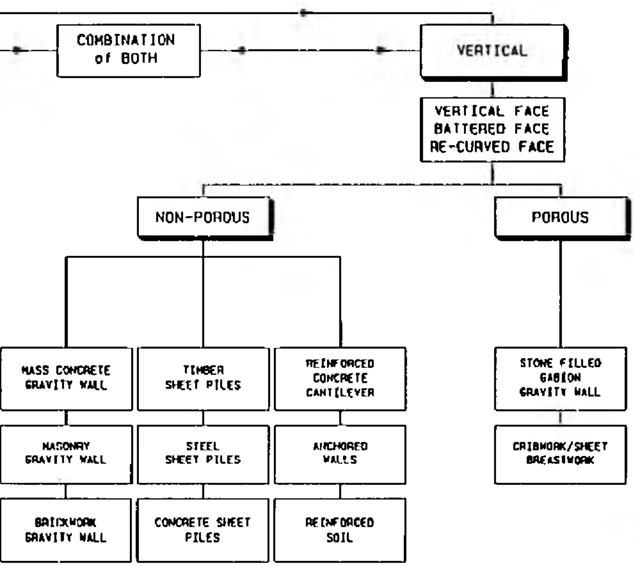


FIG. No 1.

Figure 5.16 Seawall classification



138 Seawall structure–overall concept and types

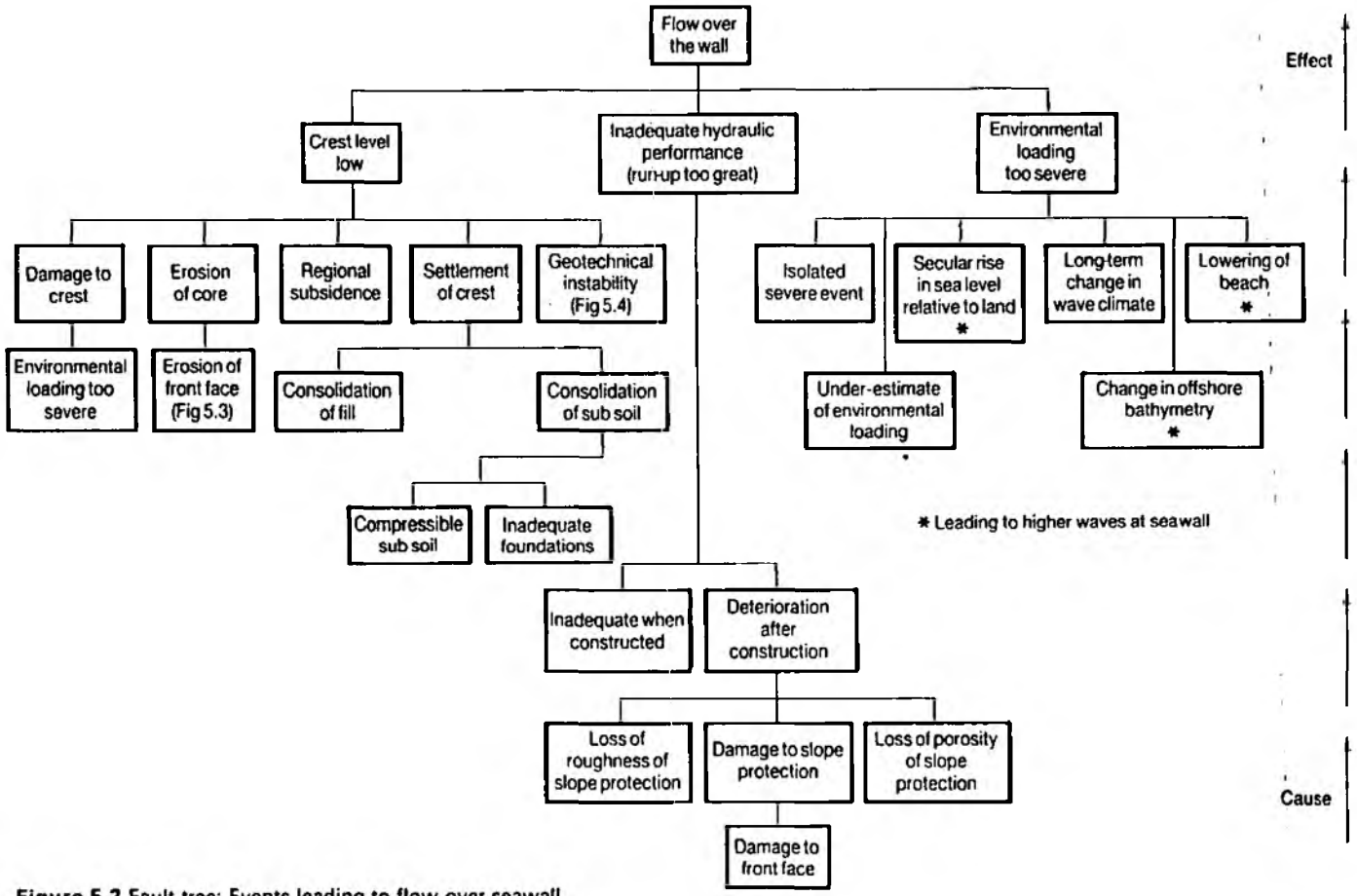


Figure 5.2 Fault tree: Events leading to flow over seawall

FIG No 2.

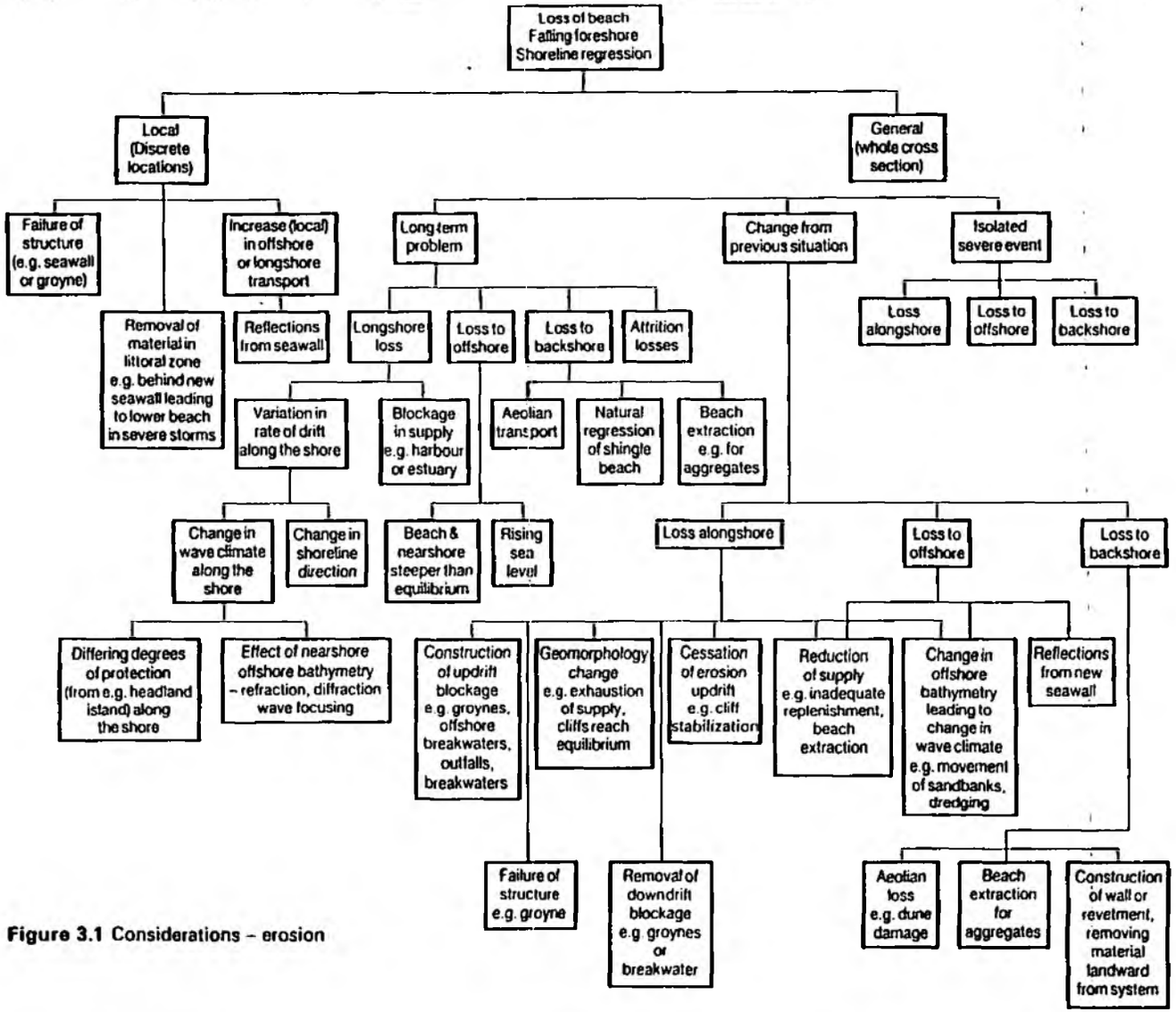
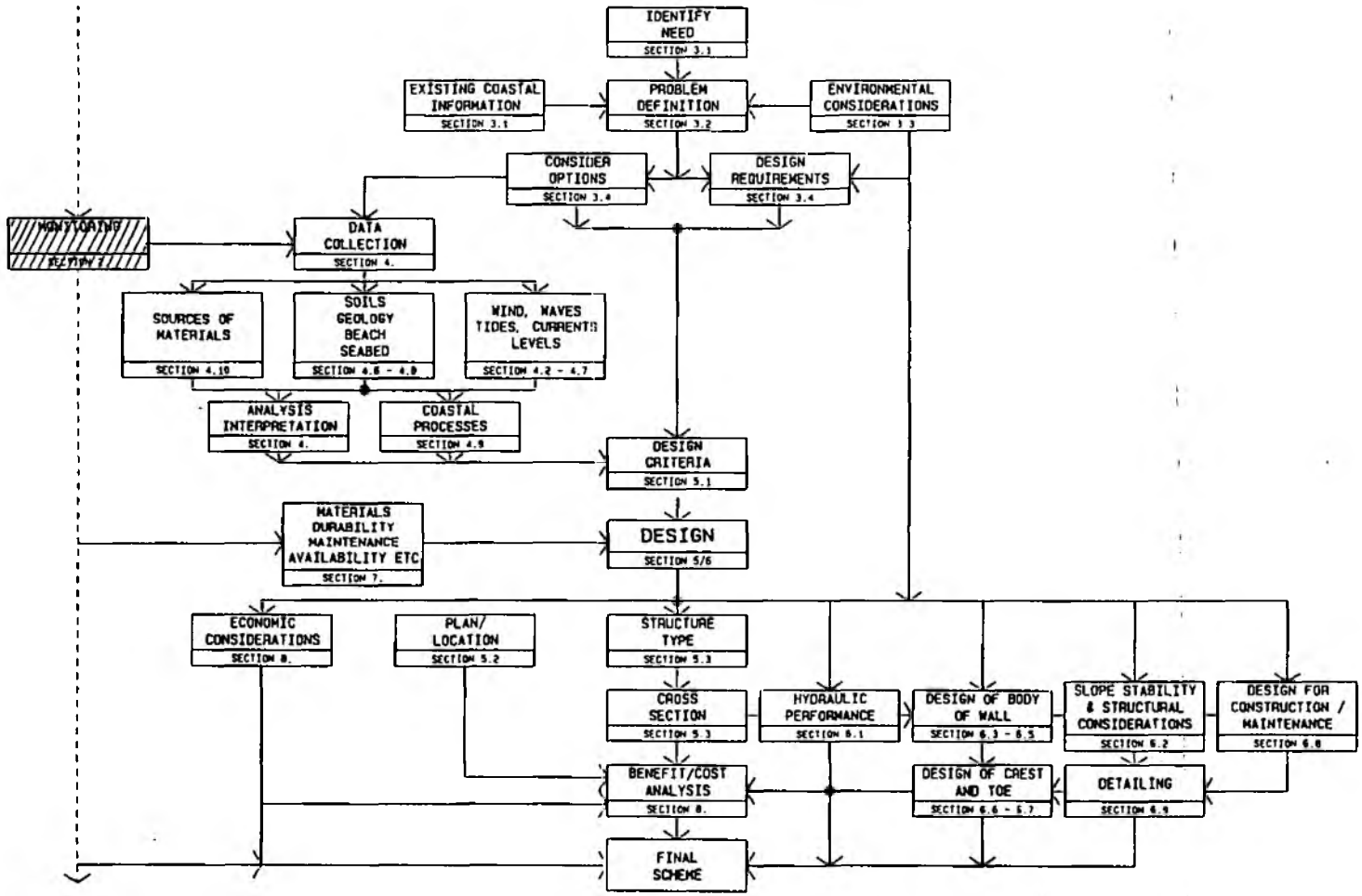


Figure 3.1 Considerations – erosion

FIG. No 3.



DESIGN FLOW DIAGRAM

FIG. No 4.