AN EXPERT SYSTEMS APPROACH TO DECISION-MAKING IN COASTAL-ZONE MANAGEMENT

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ABSTRACT

Expert systems are computer programs designed to mimic human experts in solving problems. This report investigates the feasibility of using expert systems to aid decision-makers in coastal zone management and development planning who are undertaking environmental assessments of coastal resort development proposals.

The approach adopted in the study is as follows :

First, determine what characteristics an expert system should have in order to make it suitable to address problems often encountered in coastal zone management and development planning.

Second, determine what problem-solving methods may be suitably applied using an expert systems approach, in order to derive acceptable solutions to these problems.

Third, select a narrow domain from each of three important problem areas for modelling purposes. Identify sources of expertise for each domain and extract the required knowledge from them. Encode this knowledge with the aid of a suitable expert system development tool, so as to form three prototype expert systems. Each expert system is to determine one of the following:

(a) The likelihood of occurrence of significant negative effects of septic tank effluent disposal

(b) The likelihood of exceeding the recreational carrying capacity for craft on a limited surface area of water

(c) The need for different recreational management options for craft using a surface water feature also used by birds

Fourth, construct a fourth prototype expert system whose task is to co-ordinate the others and to use their results to help the user (decision-maker) to determine suitable approaches to finding acceptable development constraints and management options for coastal resort development proposals.

One major finding is that rule-based expert systems are suitable for addressing the kinds of problem often encountered in coastal zone management and development planning provided they incorporate certain features. These features are, *inter alia*:

(1) The ability to address multiple goals at a time.

(2) The ability to combine forward and backward reasoning in different ways.

(3) The ability to call up and communicate with other programs, including other expert systems.

(4) The ability to work with mathematical variables and formulae (within the rules).

(5) The ability to work with facts and beliefs.

Another major finding is that it is feasible to use a rule-based expert system to co-ordinate others and to use their results to help the user (a multi-disciplinary expert) to determine acceptable solutions to multi-disciplinary problems in coastal-zone management and development planning.

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CHAPTER 1

INTRODUCTION

1.1 Decision-Making in Environmental Management

A new era in environmental management dawned in the early 1970's. At this time the National Environmental Policy Act of the United States of America was passed into law and the United Nations Conference on the Human Environment was held in Stockholm. In both instances the essential interaction between man and environment was recognized, as well as the need for both scientific and social perspectives in the search for solutions to man-environment problems. It is now widely accepted that the decisions required for wise environmental management must be based on value judgements as well as on both qualitative and quantitative data (Richey *et al*, 1985). Decisions in environmental management are not, generally speaking, based on an exact science amenable to deterministic reasoning and simple cause-effect modelling, but are usually made on the basis of qualitative data and on accumulated experience. Experts, including multi-disciplinary experts such as natural resource managers and planners, normally use available data by linking it via an implicit reasoning process to a choice of appropriate actions (Starfield and Bleloch, 1983).

1.2 Expert Systems

A significant development in recent years, which originates from artificial intelligence research, is that of expert systems. Expert systems are computer-based models developed to simulate the way an expert reasons, and are suited to addressing many problems which resist deterministic

solutions, but are amenable to solution by experts (Davis and Nanninga, 1985; Hayes-Roth *et al*,1983).

Expert systems supply a computer framework for investigating the rationale behind decision-making, for identifying information gaps, and for indicating where research or monitoring programs are needed (Starfield and Bleloch, 1983). They are designed to work with beliefs as well as facts, and produce output that can take the form of decisions, advice or actions (Weiss and Kulikowksi, 1984; Hayes-Roth *et al*, 1983). Examples of expert systems developed in South Africa are BURN (Starfield and Bleloch,1983) which addresses the problem of veld-burning in the Eastern Transvaal; KUDU (Starfield and Bleloch, 1986) which simulates the annual fluctuation in kudu populations in the Kruger National Park, Eastern Transvaal; and The River Conservation System (O'Keefe *et. al.*, 1986), an expert system which attempts to evaluate the conservation status of any given river system in South Africa. These expert systems, as well as many described in the literature (Alty and Coombs, 1984 ; Hayes-Roth *et al*, 1983) address a single and somewhat narrow domain of expertise.

Expert systems which address more than one domain of expertise are usually represented as two or more smaller systems (Hayes-Roth *et al*, 1983). These are designed to run together in a way that is invisible to the user (O'Hare and Bell, 1985). For the purposes of this study, the compound system is called a knowledge-based consultation system, in order to differentiate it from the single-domain expert system (Fiddes, 1985; O'Hare and Bell, 1985).

1.3 The Need for Expert Systems in South African Coastal-Zone Management

Pressures for development of holiday resort townships in coastal regions of South Africa have resulted in degradation of the natural environment and a reduction in quality of the recreation experience for tourists and holiday-makers

(Sowman and Fuggle, 1987). Holiday-makers are attracted to the coast by the aesthetically attractive but sensitive environmental features to be found there, as well as by the variety of opportunities for recreation that are offered. Often, development of holiday accommodation and recreational facilities has been allowed to proceed without taking into full account natural and socio-economic processes.

In order to help prevent poorly planned development along the coast of the Cape Province, applications for development of coastal resort townships and township extensions have, until recently, been routinely submitted to the Department of Environment Affairs for evaluation, comment and approval. This task has now been allocated to the Cape Department of Nature and Environmental Conservation of the Provincial Administration of the Cape of Good Hope.

Processing applications can take from a week to several months, and may involve considerable effort and expense. Despite this, proper environmental assessments of development proposals are seldom achieved (Fuggle and Rabie, 1983, pp499 - 515). There are two main reasons for this:

(1) obtaining expert advice in each of the specialist disciplines relevant to a development proposal assessment is often difficult

(2) South Africa has an insufficient number of qualified multi-disciplinary experts available to undertake the assessments required.

Much specialist knowledge in the environmental disciplines exists in South Africa. However, it is scattered throughout various institutions in the land and a large proportion of it is not in a form suitable to be directly used for management purposes. There is, therefore, a need to centralise this expertise, to present it in a form suitable for management purposes and to have it easily accessible to potential users. For complex issues, or where extra information is required, there is also a need to alert the decision-maker to relevant sources of expertise.

It is apparent that a knowledge-based consultation system, designed to assist the decision-maker by applying knowledge in the manner of human experts (Davis and Nanninga, 1985), would address these needs.

1.4 Aim of Study

The aim of this study is to determine the feasibility of using expert systems as a decision support system for decision-makers undertaking preliminary environmental assessments of proposals to develop resorts along the south-western Cape coastline.

1.5 Nature of the Study

In order to design and construct such a prototype knowledge-based consultation system for use in South African coastal zone management, this study addresses four problem areas normally encountered when assessing coastal resort development proposals. The first three problems require specialist expertise for their solution, whereas the fourth requires knowledge of a more general nature. The three specific problems are addressed by means of problem-oriented expert systems. These are then incorporated into a prototype knowledge-based consultation system under the control of a fourth expert system called the coordinator.

The three specialist problem areas selected are waste disposal, congestion of recreational areas during peak holiday season, and the effect of the type and intensity of recreational use on sensitive ecological features in an area. The specific aspects addressed for modelling purposes are:

(1) Likely effects of septic tank sewage disposal.

(2) Determination of the likelihood of exceeding the physical carrying capacity of a water surface area

by any combination of the following boating activities: powerboating, yachting and boardsailing.

(3) Determination of management options for boating activities on a surface water feature used by birds for feeding, roosting or breeding.

These topics were chosen because they represent important problem areas often encountered in resort proposal assessments and because of their different solution characteristics. Typically, they need different sources of expertise for their solution and they are not independent of one another. In general, problems of this type cannot be solved in isolation from one another.

Final conclusions in the assessment of a development proposal depend, in part, on solutions to each of these problems as well as on solutions to the overall problem seen in a holistic context. This latter aspect is addressed by the coordinator.

1.6 Approach

Because of constraints on manpower, finances, and computer facilities, the study is limited to available inexpensive expert system building tools suitable for use on a micro-computer.

The approach adopted in this study was as follows:

(1) Literature on the basic principles of artificial intelligence and on expert systems was studied. The aim being to understand different reasoning processes, the various ways of representing knowledge, the characteristics displayed by different types of expert system, and the kinds of problems expert systems are used to address. The main objective was to determine the principal

characteristics of an expert system that would be needed to address the problems presented in this study.

(2) The problem areas to be addressed were selected and the characteristics of relevant problem-solving expertise were determined.

(3) A suitable expert system development tool was identified.

(4) Sources of expertise suitable for addressing the specialist problems selected for the study were identified.

(5) Relevant knowledge and know-how was isolated and clarified and then represented in a form suitable for encoding into an expert system.

(6) The knowledge was encoded and the system tested in incremental stages.

(7) Once the first three specialist prototype expert systems had been developed, the fourth expert system, with the dual purpose of coordinating the operation of the others as well as of being able to aid the decision-maker to determine an overall solution to a problem, was generated.

(8) The prototype knowledge-based consultation system was demonstrated to experts and potential users. Formal testing of the prototype model was not pursued in the present study.

CHAPTER 2

EXPERT SYSTEMS: SUITABLE CHARACTERISTICS AND PROBLEM SOLVING METHODS

2.1 Introduction

Many problems in natural resource management do not have solutions able to be derived by computational methods alone and they often tend to resist precise description and rigorous analysis (Hayes-Roth *et al*, 1983, Bramer, 1982). When attempts are made to use computational methods to derive the required solutions they usually involve an unreasonable, if not unattainable, level of detail in order to do so (Starfield and Bleloch,1983). Hence a decision support system comprised only of procedural computer programs or software packages is not likely to provide the solutions needed (Quinlan, 1982). However, it is likely that expert systems, which are a novel approach to programming, allowing expertise to be encoded and distributed (Grey, 1986), will aid in providing these solutions.

Expert systems draw on the knowledge of what experts observe, what conclusions they make, or how they react to what is observed. They are able to hold an apparently intelligent conversation with the user, where questions asked are dependent on answers given to previous questions (Starfield and Bleloch, 1983). They are also able to justify conclusions and explain their reasoning. Expert systems can perform as skilful and cost-effective consultants (Bramer, 1982).

Important characteristics of an expert system include (Hayes-Roth *et al.*, 1983):

(1) The selection of a demonstrably believable solution.

(2) The ability to solve problems quickly.

(3) The ability to explain reasons for decisions.

(4) The utilization of uncertain knowledge.

(5) The ability to handle conflicting information.

(6) The ability to handle rapidly changing knowledge.

In this chapter the types and attributes of expert systems are discussed and a suggested problem-solving strategy is presented.

2.2 Types of Expert Systems

Expert Systems may be broadly classified into two types, namely, frame-based systems and production systems (Hayes-Roth, 1985). Frame-based systems are expert systems in which knowledge is partitioned into separate structures called frames. Each frame is centered about an object (or a class of objects). Properties of that object occupy positions, called slots, in the frame. Each slot is linked to the object by a relationship such as "was born on" or "height is", amongst others. The concept of a slot in a frame is similar to that of a record entry in a row of data in a file. Frames may be said to represent descriptive, or static, knowledge (Rich, 1983). They group the descriptive elements of an object or event together, thus allowing them to be accessed and processed together (Alty and Coombs, 1984).

Production systems (or rule-based systems) are expert systems in which knowledge is stored in the form of production rules (Newell and Simon, 1972). A production rule is a rule of the type: **IF A THEN B** (Alty and Coombs, 1984; Rich, 1983). In other words, IF precondition A is fulfilled THEN conclusion B is assumed to hold true. In such a rule,

the IF part determines the applicability of the rule and the THEN part describes the action to be performed if the rule is applied (Rich, 1983). A and B represent statements to which a truth value may be assigned. An example of a production rule is: IF Caspian tern are breeding in the vicinity THEN prohibit powerboats from using the area.

A production rule can have multiple preconditons (a pattern of data) in the IF part and more than one conclusion in the THEN part (O'Hare and Bell, 1985; Pau, 1986). An example of such a production rule is:

> IF A AND B AND C THEN P AND Q
>
> i.e. if preconditions A, B and C are met, then the conclusions P and Q hold true.

Whereas frame-based systems are good at representing static or descriptive knowledge, production systems are more suitable for representing problem-solving expertise (Alty and Coombs, 1984; Hayes-Roth *et al*, 1983; Hayes-Roth, 1985; Rich, 1983). The latter is so because all problem-solving expertise may be formulated in rules and experts tend to find that this formulation comes naturally to them (Newell and Simon, 1972; Hayes-Roth, 1985). In fact, Hayes-Roth (1985), Alty and Coombs (1984), and Rich (1983) record that the best currently available approach to formalizing and codifying problem-solving expertise is through production systems.

This study, then, is concerned with the applicability of production systems to environmental evaluation of coastal resort development proposals.

Hayes-Roth (1985, p. 921) lists the kinds of expertise suitable to be modelled by rule-based systems:

> Specific inferences that follow from specific observations.
>
> Abstractions, generalizations and categorizations of given data.

Necessary and sufficient conditons for achieving some goal.

Likeliest places to look for relevant information.

Preferred strategies for eliminating uncertainty or minimizing risk.

Likely consequences ensuing from hypothetical situations.

Probable causes of symptoms.

Benefits of production systems include the following (Alty and Coombs, 1984; Rich, 1983; O'Hare and Bell, 1985; Hayes-Roth, 1985; Pau, 1986):

(1) They are generally applicable over a wide problem domain

(2) New rules may be easily added to account for new situations with little disturbance to the rest of the system occurring as a result

(2) They provide an easy way to furnish explanations

(3) They are easy to construct.

A major drawback is that production systems in their unstructured form cannot cope efficiently with large rule files (Pau, 1986; Alty and Coombs, 1984). A further drawback is that, although knowledge may be made explicit in a production system, its function tends to remain hidden (Aikins, 1983).

The following sections deal with the different characteristics and attributes of production systems.

2.3 Production Systems

2.3.1 Components of Production Systems.

A production system has three basic components:

(1) A rule file consisting of a set of production rules

(2) A temporary data storage facility (or working memory) which stores data which have been assigned truth values (or which are known to be true)

(3) A rule interpreter, a special program which tests rules for applicability and then processes them according to a certain procedure and which also determines a way of resolving conflicts when two or more rules apply at the same time (Alty and Coombs, 1984; Hayes-Roth *et al*, 1983; Bramer, 1982).

2.3.2 Reasoning Procedures.

There are two basic reasoning procedures in a production system: forward and backward reasoning. Essentially, forward reasoning is reasoning from known data towards unknown (or unforseen) results, whereas backward reasoning is reasoning from what is to be proved (unknown) to what is given (known) (Winston, 1977). These two aspects are now discussed in further detail.

2.3.2.1 Forward Reasoning

In forward reasoning, items of information (statements which are true, for example) which are entered by the user (or from another source) are placed in the working memory. The rule interpreter compares the pre-conditions of a rule with each item of information in working memory then, if items are found which match all the preconditions of a rule, the conclusions of the rule are considered to be valid (i.e. true). This is known as executing, or firing, the rule. A valid conclusion may then cause an item of information to be added to the working memory or else deleted from it (Pau,

1986; Alty and Coombs, 1984; Pollitt, 1986). Firing a rule may cause other actions to be carried out, for example: an instruction may be sent out to cause a computer program to be run, or, it may cause control to be passed to the user (Hayes-Roth *et al*, 1983). Another rule is then tested against the (possibly) modified contents of the working memory, and then another, until all the rules are tried at least once, and then the cycle may repeat. Normally, the procedure ends when no more matching rules are found or when every rule has been executed at least once (Pollitt, 1986; Hayes-Roth, 1985).

The process of reasoning from the start state of the working memory (which consists of known facts) to its end state (which is unknown) is called forward reasoning (or forward chaining) (Rich, 1983; Winston, 1977). A forward-reasoning production system is said to be data, pattern, or condition driven (Bramer, 1982).

2.3.2.2 Backward Reasoning

The process of reasoning backwards from a goal (or what is required to be proved) towards the known facts is called backward reasoning or backward chaining (Rich, 1983; Pau, 1986; Winston, 1977). Backward reasoning is similar to the logical procedure used by mathematicians in proving a theorem (Rich, 1983). A production system which attempts to reason backwards is said to be goal-driven (Bramer, 1982).

In the following simplified description of how a backward reasoning system works, rules are limited to having single preconditions and single conclusions:

The expert system is first given a goal to establish (i.e. a hypothesis to prove or disprove). The conclusion to each rule is then examined by the rule interpreter to see if it matches the goal. If such a rule is found, the precondition of the rule is tested to determine if it matches any data in the working memory. If a match is found, the goal is proven true.

If no match is found then the precondition is set up as a temporary subgoal and the conclusion in each of the other rules is examined to see if any match this subgoal. If any do then the precondition of the new rule is tested against the data in working memory. If a match is found between the precondition of the rule and an item of data in working memory then the goal is proven true. However, if no match is found, this precondition becomes the next subgoal and the cycle is repeated.

This recursive procedure continues until either the goal is proven true or else there are no more rules left to try. If the latter is the case, the user may be requested to supply further information. The goal is not proven true if the required information is not supplied, or if information contrary to that required for positive proof is given. (van Melle, 1979; Davis and Nanninga, 1984; Alty and Coombs, 1984; Winston, 1977)

2.3.2.3 Examples

Two examples to explain forward and backward reasoning follow:

(1) The first example is used to illustrate the basic concept of forward and backward reasoning. Suppose the rule file contains only two rules, that F represents an item of information which is known to be true at the start of a consultation and that the objective, or goal, is to prove G true.

```
RULE 1:     IF  C  IS TRUE  THEN G  IS TRUE
RULE 2:     IF  F  IS TRUE  THEN C  IS TRUE
```

In forward reasoning the consultation is started by comparing the IF part (or precondition) of each rule to the known data. In this case the precondition of rule 2 matches the known data, F. This rule's conclusion, represented by C, is then added to the working memory. The precondition of rule 1 is then compared to each item of known data, and it matches item C. The conclusion of rule 1 is

therefore added to what the system "knows". The working memory now has the data F, C and G in it. Because they are all in working memory, they are true, so G, the goal required, is true.

In backward reasoning, the consultation is started by comparing the conclusion in each rule (the **THEN** part) to the goal, G. The conclusion in rule 1 matches the goal. The precondition in rule 1 is therefore compared with the data, F, in working memory. No match is found. This rule's precondition, C, is now set up as a subgoal. The conclusion in rule 2 is then compared with this subgoal and a match is found. The precondition, F, in rule 2 is therefore tested against the data in working memory and, this time, a match is found. So G is proved true.

(2) The second example, a modified version of that given by Waterman (1977), is used to explain particular characteristics of forward and backward reasoning in a production system. Figure 1 is used to illustrate this example.

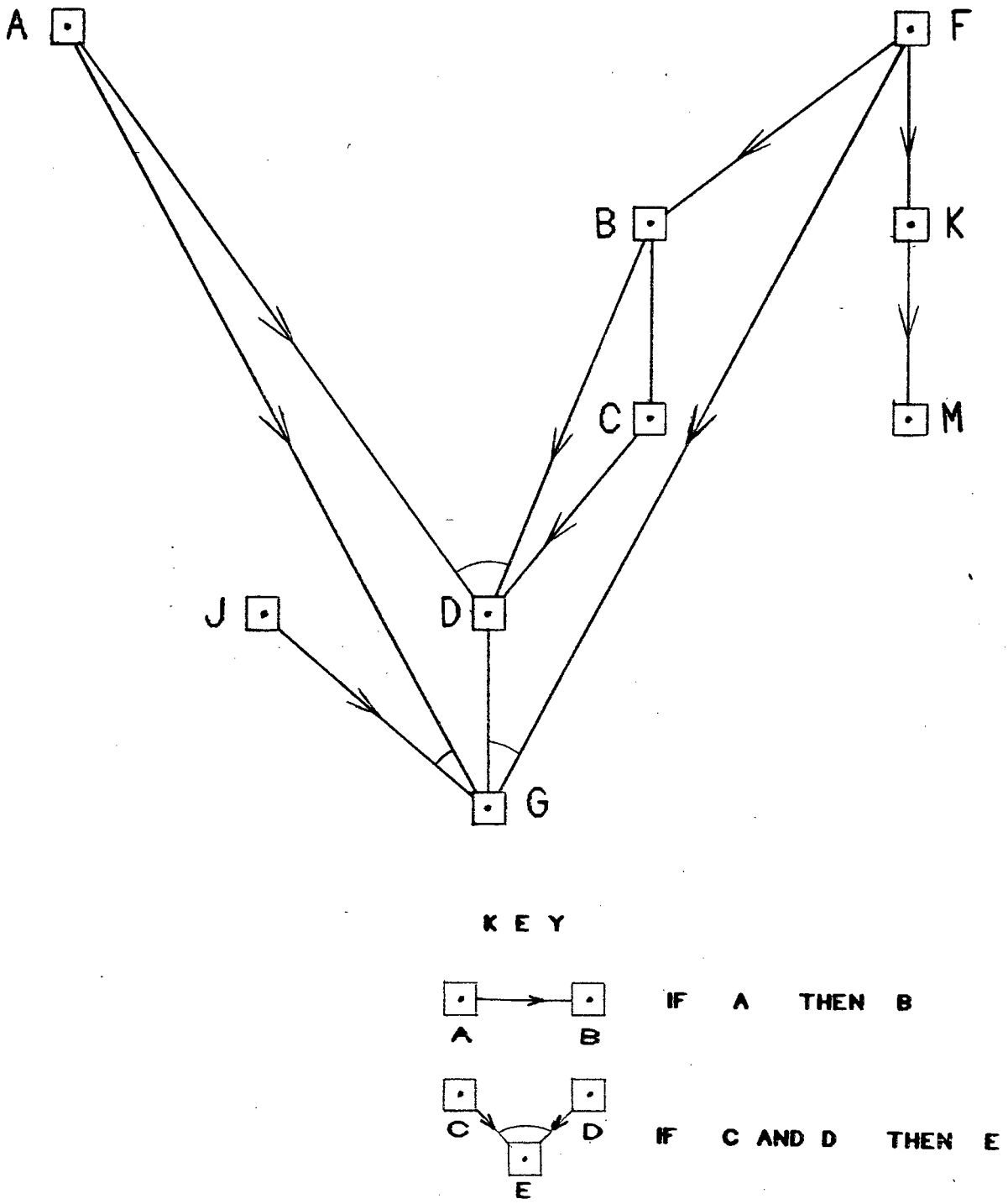

Figure 1: Flow-diagram Used to Illustrate Forward and Backward Reasoning

Letters are used for data elements in working memory and are considered true if they are in it and unproved or false if they are not.

DATA IN WORKING MEMORY AT START.: A, F

GOAL : Prove G is true

RULES :-

RULE NO.	PRECONDITIONS	CONCLUSIONS
1	A AND B AND C	D
2	D AND F	G
3	A AND J	G
4	B	C
5	F	B AND K
6	K	M

(a) Using Forward Reasoning

Control Strategy: Try rules in order, repeat the cycle
Execute applicable rules once only

Procedure:

First Round

Since F is true Rule 5 fires : Add B & K to wrkg memory
" K " " " 6 " : " M " " "

Second Round

Since B is true Rule 4 fires : Add C to wrkg memory

Third Round

Since A, B & C are true Rule 1 fires : Add D to wrkg memory

Since D & F are true Rule 2 fires : Add G " " "

Results: A, F, B C, D, K and M are true.
The goal, G is proved true.
J remains unproved.

From this example on forward reasoning it may be seen that item, M, is proved true even though it may not be specifically sought. However, this may be useful since M could be an instruction to the

user, or a command to run another computer program so as to return needed data to the expert system. Also that if item, J, had been added to short-term memory at the start, G could be proved true (or evaluated) through two different reasoning processes, one as a result of D and F being true (rule 2) and the other as a result of A and J being true (rule 3). Should the results clash, a conflict resolution strategy would be needed to either select the applicable rule(s) or to combine the results using some formula or suitable algorithm (see sect 2.5). Further, J could represent an extra item of information volunteered by the user at the start of a consultation, and this could then be used to modify or check errors in the data or in rules (Pollitt, 1986).

(b)Using Backward Reasoning

Control strategy: Backward reasoning.
Try rules in order, until an applicable rule is found, then start at the top again and repeat.

Given: A and F are true.

Goal: Prove G is true.

Test for:	Applicable rule:	Next subgoal(s):	Comments:
G	2	D	F is true (given)
D	1	B and C	A is true (given)
B	5		F is true (given) so B is true (rule 5)
C	4		B is true (rule 5) so C is true (rule 4)

Hence, since A, B and C are now proved true, D is proved true (rule 1). Since D and F are then both true, G is proved true (rule 2). Thus the goal, G, is proved true. A, F, B, C, and D are also true and K, M, and J were not considered.

From this example of backward reasoning it may be seen that K and M were not evaluated in the backward reasoning procedure. This illustrates the fact that a backward reasoning system only asks those questions that are relevant to the goal being evaluated (Starfield and Bleloch, 1983; Winston, 1977). Further, the rule containing J as one of its preconditions (rule 3) was not tested during the backward reasoning procedure. However, if the control strategy is changed to: "Try all rules in order, use all applicable rules found", then J would be tested as it has a direct effect on the truth of G. In this case, however, no rules have J in their conclusions and as a consequence the user could be asked to supply a value for J, or a default value may be assumed (e.g. "If there is no evidence to the contrary, assume J is true") or else the rule may be ignored. If a value for J had been supplied, two different rules (rule 2 and rule 3) would then try to give a truth value to G and, as in the example on forward reasoning, a conflict resolution strategy would be needed.

2.3.2.4 When to use Forward and Backward Reasoning.

If the problem is one in which every bit of advice, decision, or action relevant to the given data is needed, then a forward reasoning system is likely to be most suitable (Winston, 1977). Forward reasoning appears more suitable for those problems where the kinds of solution required are not known: for example, for problems where known effects are shared by several unknown causes, or where known causes result in several unknown effects.

If the problem is to evaluate a particular objective, goal or hypothesis, and requests for redundant information are to be avoided, then a backward reasoning system is likely to be the most suitable (Winston, 1977). Following from this it may be hypothesized that a backward reasoning strategy is

more appropriate for problems where the user already knows the kind of solution that is needed.

Sometimes the use of both forward and backward reasoning may be needed. For example, in a backward-reasoning system, an external program may need to be called so as to supply needed data. Forward reasoning would then be required for those rules devoted to calling up the required program.

2.4 A Suggested Reasoning Strategy for Typical Problems in Coastal Zone Management.

Problems in natural resource management often require solutions in the form of options (or possible alternatives) and these options can have different component parts. For example, in the assessment of a resort development proposal, two suitable options in which the first has three component parts and the second has two, could be:

(1) Reduce the number of proposed erven by at least 25%
AND
set the proposed resort back from the surface water feature by at least 150 metres
AND
construct a suitable slipway to sea for powered craft.

(2) Reduce the number of proposed erven by at least 50%
AND
set the resort back from the surface water feature by at least 100 metres.

As this kind of problem typically has several possible solutions and each solution is likely to have several parts to it, it appears that a problem-solving strategy using forward reasoning is required. But use of forward reasoning only is likely to require that the rules be ordered so that rules that derive information for other rules come before them. As rules may need to be ordered for other more important reasons, or else not at all, it may be more suitable to use backward reasoning to derive this information from other rules when it is needed (Huntingdon, 1987). Thus an expert system which uses a reasoning strategy

of forward and then backward reasoning now appears more suitable for problems of this type.

One kind of problem often encountered in natural resource management involves the determination of likely causes of a known impact. Suppose that a coastal lake is being rapidly subjected to an invasion of a single species of reed in shallow waters near the shore on one side of the lake. Suppose also that there currently exist large mats of green, scum-like algae along the water's edge on the same side of the lake. An official involved in coastal-zone management, although suspecting that eutrophication of surface waters is somehow involved, may not be aware of all the likely causes. For example, the reed growth may be aided by silt carried down from ploughed farmlands by runoff. The scum-like algae and the prolific reed growth may also be the result of eutrophic surface waters, which may in turn be due to fertilizers being washed down from the farmlands as a result of runoff. On the other hand, the inflow of groundwater, which could be contaminated by septic tank effluent from a holiday resort in the vicinity, may be a significant factor both in the formation of the scum-like algae along part of the shoreline and in the prolific reed growth.

In a production system, forward reasoning could be used to establish these and other possible (contributing) causes and backward reasoning could be used to derive needed information from other rules.

2.5 The Basic Control Strategy Used.

The basic control strategy for participating expert systems in the prototype model is:

(1) Use forward then backward reasoning.
(2) Try all rules in the order that they appear in the rule file.
(3) Fire applicable rules once only.

The reason for trying all the rules (i.e.not stopping at the first applicable one) is that there is a need to obtain all

the decisions and recommendations relevant to the information available. This is why forward reasoning is needed. All the possible solutions must be addressed and so all the related rules need to be applied. The reason for applying a rule once only is to help prevent a piece of evidence being counted more than once, and also to prevent a reasoning sequence from looping back on itself and so becoming caught in an unending cycle.

The selection of an effective control strategy for the type of problem addressed is an important task in the building of expert systems (Alty and Coombs, 1984; Rich, 1983)

2.6 Uncertainty

2.6.1 Working with Partial or Uncertain Knowledge

All knowledge is assumed to be able to fit into simple production rules (Newell and Simon, 1972). However, if the knowledge is partial or uncertain, it is considered more effective to have a (probabilistic) weighting factor attached to each rule and a mechanism within the production system which will combine these weights in a realistic way (Rich, 1983; Hayes-Roth *et al*, 1983; Shortliffe, 1976). Ways of combining weights for rules working side-by-side (i.e. in parallel) and for rules linked serially, may be best illustrated by the following examples:

(1)Combining weights for rules working in parallel.

Assume that two rules have the statement, B, in their conclusions, as follows:

IF A is valid **THEN** it is likely (.7) that B is valid.
IF C is valid **THEN** it is likely (.5) that B is valid.

The weighting factors in the rules are .7 and .5 respectively, where the value 1 represents certainty and 0 indicates that B has no evidence to support it. If the preconditions of both rules are

satisfied, then the truth value of B could be computed by taking the average of the weighting factors, by taking the maximum value, or by treating the weighting factors as if they are independent probability estimates, amongst others.

(2)Combining Weights for Rules Linked Serially.

Assume that two rules in a rule file are as follows:

IF R is valid **THEN** it is likely (.5) that S is valid.
IF S is valid **THEN** it is likely (.8) that T is valid.

Assume that the statement, R, is known to be valid (i.e. true).

A possible way of calculating the truth value of the statement, T, is to multiply the individual weightings (.5 and .8) together and to assign the result (.4) to T. Another approach is to assign weights to T, dependent on each truth value of S, directly in the rules. This could be done by replacing the second rule by:

IF it is likely (.5) that S is valid **THEN** it is likely (.5) that T is valid.

T would then be assigned a value of .5.

In production systems, evidence may be combined or selected in order to increase the reliability of the solution (Bramer, 1982; Hayes-Roth *et al*, 1983; Hayes-Roth, 1985).

2.6.2 Limitations to Methods of Combining Probability in the Selected Expert System Building Tool.

Due to limitations inherent in the expert system building tool used in the present study, weightings are individually assigned to partially true statements in rules linked serially. For rules working in parallel, the option of averaging the weights is selected, due to the lack of a preferred alternative. A preferred approach for the latter,

but one which is not presently catered for in the building tool, is to take the maximum value of the individual weights relevant to a particular conclusion. The reason for this is that rules in the prototype expert systems are constructed to account for partially complete knowledge, and so can address overlapping sets of data. For example, consider the following two rules:

```
IF A AND B           THEN  T (0.5)
IF A AND B AND C     THEN  T (0.9)
```

The weighting assigned to T reflects a value judgement which is dependent on the completeness of the knowledge that supports it, as well as on the inherent uncertainty within that knowledge. If only A and B are known to be true then the first rule applies and T is assigned a truth value of 0.5. If C is also known to be true then only the second rule should apply and T should be assigned a value of 0.9. However, under the present control strategy, both rules would fire as they are both applicable (see sect. 2.5) and so some method of selecting the appropriate weighting is needed. Combining these weightings so as to give an average value (0.7) would result in an estimate that is too low. Combining them as independent probabilities, on the other hand, would give an estimate (0.95) that is too high. Taking the maximum value of the two weights is what is wanted.

Other approximate estimation methods are described in Alty and Coombs (1984), Hayes-Roth *et.al.*(1983), Rich (1983) and others.

Simple, but fallible, weighting (or probability) evaluation methods are generally suitable for problems where the error content of data and weighting factors of rules are only roughly estimated (Rich, 1983; Hayes-Roth *et al*, 1983). These methods can be said to provide an informal weight that reflects confidence in conclusions drawn. Inference procedures using these methods are said to involve inexact or plausible reasoning (Bramer, 1982; Alty and Coombs, 1984; Hayes-Roth *et al*, 1983). More rigorous probability estimation methods, such as that of Bayes, may be warranted for problems in which the error content is precisely known

and which require accurate solutions (Gaschnig, 1982). However, both Hayes-Roth *et al*, (1983, p94) and Rich (1983, pp 193, 197) express caution over the use of rigorous statistical techniques in production systems.

In the present study, the scope is limited to production systems which use inexact reasoning strategies.

2.7 The Concept of Least Commitment .

Production systems which use inexact reasoning methods are said to be able to reduce the chances of discarding a good solution by retaining a limited number of possible solutions earlier in the consultation and then, as further information becomes available at a later stage, by re-assessing and refining these (Alty and Coombs, 1984; Hayes-Roth, 1985). The concept involved here is known as the least commitment principle, which states that decisions (or solutions) should not be made arbitrarily or prematurely, but postponed until sufficient information becomes available (Alty and Coombs, 1984, p. 92; Hayes-Roth *et al*, 1983, p. 106).

Multi-disciplinary problems of the type addressed in this study display key characteristics which suggest a problem-solving approach using the least-commitment principle. These characteristics are looked at in closer detail in the next section.

2.8 Problem-Solving Characteristics Required for Solution to Resource Management Problems.

2.8.1 The Applicability of the Least-Commitment Principle to Resource Management Problems.

Problems of a multi-disciplinary nature, such as those which occur in natural resource management, usually consist of interacting sub-problems within the participating disciplines. A solution to one sub-problem will normally

depend on or affect the solution to others (Hayes-Roth *et al*, 1983). It is therefore often not possible to specify a solution to one sub-problem unless progress has been made in solving others. Also, the order in which sub-problems are addressed is usually not able to be established beforehand, but depends upon information generated as the process continues. Often, a single optimum solution to a sub-problem is not necessary, whereas a close enough approximation is sufficient. In fact, any solution that satisfies a given set of requirements or constraints may be all that is needed (Alty and Coombs, 1984; Hayes-Roth *et al*, 1983; Rich, 1983).

According to Rich (1983, p. 258) the least-commitment principle is an effective approach to finding an overall solution to a complex (multi-disciplinary) problem, in which solutions to sub-problems are incompletely specified until the maximum amount of information is gained, then the specifications are completed in such a way that no conflicts arise. This may imply that a recursive procedure has to be adopted for situations in which conclusions are drawn, given only partially correct information. It may be necessary, for example, to make an assumption and then later to return and revise this because of new information generated. A related concept to this is that of reasoning by default, in which a fact may be assumed to be valid unless there is information (or evidence) to the contrary (Hayes-Roth *et al*, 1983; Rich, 1983).

2.8.2 A Suggested Problem-Solving Approach

A suggested approach to solving this type of problem using the least commitment principle is as follows:

(1) Select a sub-problem whose solution is likely to have a significant effect on the solutions of the other sub-problems, and for which there is sufficient information to start on.

(2) Proceed to solve it, making assumptions using reasoning by default where necessary, retaining a limited number of possible solutions which are

weighted or ranked according to their likelikhood of being correct.

(3) Using any newly available information, repeat steps (1) and (2) on the next applicable sub-problem, and then on following sub-problems until each applicable sub-problem has been tried at least once for solutions. (Note that in further trial rounds only those sub-problems affected by a change in assumptions need to be tried for solutions: see step (5)).

(4) Examine the results (i.e. recommended constraints, likely impacts, management options and advice) to each sub-problem, and determine any problem-solving strategies likely to bring about alternative overall solutions which accomodate these results. In other words, the overall solution should, *inter alia*, satisfy the constraints, take into account the management options and reduce the likelihood of negative impacts to acceptable levels. These overall solutions should also accomodate management objectives and priorities for the area concerned.

Each problem-solving strategy involves the revision of the assumptions taken in solving the sub-problems. An example of such a strategy follows:

> reduce the number of erven proposed for a coastal resort by 10% and now assume that no powered craft will be allowed to use the body of water in question).

(5) Select an applicable problem-solving strategy, then determine which sub-problem needs to be addressed first. Repeat steps (2) and (3). Examine the final results again to see how close they are coming to those wanted. If they are not close enough to form an acceptable solution, a suitable revision of assumptions may be made and the procedure repeated. If no solution is forthcoming, an alternative problem-solving strategy may be pursued. If the

alternative strategies fail, then possible options are, *inter alia*, to turn down the proposal, to consider partial solutions satisfying the most important issues, or else to consider a totally different approach.

An example of how a knowledge-based consultation system may be used to model the above problem-solving approach and how it may be applied to a specific problem appears in the next section.

The least commitment principle, as it is used in the above approach, involves co-ordinating the creation of solutions with availability of information, and causes the focus of problem solving activity to move to the sub-problems most likely to respond effectively (Hayes-Roth *et al*, 1983). In the present study, an attempt is made to develop a prototype knowledge-based consultation system which uses the above approach to address environmental assessment (and development planning) problems in coastal zone management.

2.9 The Prototype Model

2.9.1 Components of the System

There is usually a need, when addressing multi-disciplinary problems, to integrate diverse bodies of knowledge and different reasoning methods into the same problem-solving system (Hayes-Roth *et al*, 1983). In other words, access to different forms of knowledge, data and know-how is needed for the effective solution of sub-problems as well as for assessing the overall solution. The suggested approach to solving this type of problem is to encode these different forms of expertise into separate expert systems, so that the different kinds of knowledge can be represented suitably in each, then to incorporate these into a problem-solving system under the control of another expert system.

The prototype system envisaged for the present study is one involving four production systems. The first three are

problem-oriented expert systems (or specialist systems), whereas the fourth (the coordinator, or generalist system) is designed to control the operation of the others as well as to aid in determining an overall solution to problems. The order in which each specialist system is run is determined by the coordinator, which relies on information made available as the consultation proceeds. The latter also has the task of presenting results to the decision-maker and recommending suitable approaches towards obtaining acceptable overall solutions.

2.9.2 The Consultation Procedure

At the start of a consultation, the co-ordinator asks the user for contextual information which is applicable to more than one specialist expert system. Using this information, it calls the most relevant specialist system, and passes needed information to the latter. The specialist system then takes control and asks the user for information specifically needed for its task. If the user is not certain of any information, a default value may be assumed, or else the specialist system may abandon its current line of reasoning and follow another in order to gather evidence to determine the likely information required. This data is then presented to the user for approval, and the previous line of reasoning may then be resumed. A further option open to a specialist expert system is for it to call another expert system or outside information source to obtain data to enable it to complete its task.

After completion of its task, or if it has no further information to proceed further, the specialist system passes data back to the co-ordinator, and the latter resumes control. The co-ordinator may use this information in deciding which specialist system to call up next. The next relevant specialist system is called, and the procedure is repeated. The procedure is then repeated with other applicable specialist systems until they have all been tried for solutions (The present study addresses three such systems). Results from each specialist system may be in the form of a likelihood of an impact, specific management

options, recommended constraints on the proposed development and advice. The coordinator selects the information needed to determine possible options to pursue in order to approach an overall solution. These options are then presented to the user (decision-maker), who selects a suitable one (or a combination of several), changes the assumptions indicated, and repeats the consultation by calling up the coordinator to work with this new information. At the end of this consultation the results are again presented to the user. If the likelihood of a significant impact occurring is sufficiently reduced and the selected management options are acceptable to the user, the latter may accept the results presented. The corrected assumptions then become constraints applicable to the development proposal. Otherwise, further revisions of input data can be made and the consultation repeated.

2.9.3 An Example

Suppose that an estuary, closed to the sea for most the year, is currently being used by powerboats, yachts and sailboards. Assume, also, that the estuary is an important feeding, roosting and breeding area for some species of bird, and that a resort development, using septic tanks for sewage disposal purposes, is proposed for the area.

(1) Given the above information, the coordinator selects the septic-tank effluent disposal problem. Assume that recommendations are:

   (a) Reduce the total number of erven proposed. Weighting: 7/10

   (b) Consider alternative sewage disposal options. Weighting: 9/10

   (c) Move the development further away from the surface water feature. Weighting: 9/10

On the weighting scale, 10/10 indicates certainty and 0/10 indicates that there is no evidence to support the recommendation.

(2) The coordinator then selects the sub-problem dealing with the likelihood of exceeding the physical recreation carrying capacity of the surface water feature for powerboating, yachting and boardsailing. Assume that the results show that the likelihood of exceeding the physical recreation carrying capacity of the water surface area in question, when all erven, including those presently proposed, are fully developed, is 9/10

(3) The coordinator then selects the sub-problem dealing with the sensitivity of birds to recreational craft use. Assume possible options are:

(a) Prohibit powered craft from using the area in question. Weighting: 9/10

(b) Consider nature conservation status for the area in question. Weighting: 9/10

(c) Consider temporal zoning for the craft in question. Weighting: 7/10

(d) Consider spatial zoning for the craft in question. Weighting: 5/10

(4) The coordinator assesses the solutions to the three sub-problems, and concludes that there are three ways of approaching a solution to the overall problem. The reasoning procedure is as follows:

(a) Consider prohibiting powered craft from using the area in question, then, as this reduces the likelihood of the recreational carrying capacity being exceeded, re-calculate the likelihood of exceeding the physical recreation carrying capacity for yachting and boardsailing only. If this is reduced to acceptable levels, then consider, next, the three recommendations

for the septic tank effluent disposal sub-problem.

If a serious reed growth problem and a health hazard to boardsailors is likely to occur as a result of likely contamination of surface waters by septic tank effluent, and management priorities are towards conservation, then more stringent precautions against possible eutrophication of the surface water feature may be required, for example: install a containerized sewage system. If, on the other hand, a certain likelihood of eutrophication of the surface water feature is acceptable, then the options of setting the proposed development further back from the boundary of the surface water feature, or of reducing the total number of erven, or both, may be viable. The option of reducing the total number of erven could be favoured if the likelihood of exceeding the physical recreation carrying capacity needs to be reduced still further.

(b) Consider temporal zoning. As temporal zoning reduces the likelihood of the recreational carrying capacity being exceeded, calculate this likelihood for powered craft by themselves, and for yachts and sailboards together. If this likelihood is still too high, say, for powerboating, then a further option is to decrease the number of proposed erven.

If the erven are decreased sufficiently to acceptably reduce the likely impact of sewage effluent on the environment, then this may be an acceptable overall solution, depending on management priorities for the area.

If management priorities are towards recreational development, then alternative sewage disposal options and the provision of alternative recreational facilities, such as a boat ramp to sea (for powerboats) may be considered instead.

(c) Consider spatial zoning. This option appears to be the least promising as it does not aid in reducing the likely congestion effects at the water surface feature and is also not a heavily weighted option as a solution to the third sub-problem.

However, if management priorities are toward recreational development, and there is to be provision of alternative recreational facilities, and if other similar water surface features suitable for conservation purposes exist in the area, then this option may be a suitable one to use together with (for example) an alternative sewage disposal option, as a solution to the overall problem.

The integrated system is, for the purpose of this study, termed a knowledge-based consultation system so as to differentiate it from the indvidual expert systems of which it is composed. The consultation system uses different ways of reasoning as well as diverse sources of knowledge, and operates under the least-commitment principle using a constraint-satisfaction technique (Hayes-Roth *et al*, 1983).

2.10 Two Expert Systems Which Use the Least-Commitment Principle

Examples of two well-known expert systems which use the least-commitment principle are:

(1) MOLGEN (Stefik, 1980) which is designed to assist biologists in designing experiments in molecular genetics. MOLGEN formulates constraints, then propagates new constraints from the old ones, and finally tries to satisfy them (Alty and Coombs, 1984).

(2) HEARSAY-III (Erman *et al*, 1980), which is designed as a speech-understanding system. It is organised as a group of co-operating, independent specialist expert systems which communicate by means of a "blackboard" (a data file). Each specialist expert system contains a different type of knowledge which is applicable to the central problem (Hayes-Roth *et al*, 1983, p. 21, 40, 115). When a specialist system is activiated, it examines the current information in the blackboard file and then uses it to create a new hypothesis which it adds as information to the file, or else it may modify existing information in the file. The goal of the system is to create a single hypothesis that represents a solution to the problem. (Rich, 1983, p. 278). A scheduler controls the order in which expert systems are activiated (Hayes-Roth *et al*, 1983).

2.11 Conclusion.

To summarize, the problem characteristics suitable for solution by a forward-reasoning strategy (with backward reasoning where needed),the least-commitment principle, and multiple co-operating production systems are:-

(1) Partial or uncertain knowledge is present.

(2) The overall problem can be subdivided into nearly independent sub-problems whose solutions interact.

(3) The order in which sub-problems are to be addressed cannot be pre-determined.

(4) Sub-problems need diverse sources of knowledge and different reasoning methods for their solution.

(5) Solutions to sub-problems cannot be evaluated accurately.

(6) There are several combinations of possible solutions to choose from.

In the next chapter, the construction and testing of the prototype model is discussed.

CHAPTER 3

THE PROTOTYPE MODELS

3.1 SEWAGE: The Septic Tank Effluent Model

3.1.1 Introduction

Unwise disposal of septic tank effluent can have far-reaching effects. If improperly treated effluent comes to the surface on land it may cause unsightly scums and bad odours and become a health hazard (Clark, 1977; Davies and Day, 1986). If improperly treated effluent reaches the water table, and if water for human or animal consumption is extracted from a borehole in the vicinity, then negative implications for health are likely (Davies and Day, 1986). If groundwater, contaminated with improperly treated effluent, seeps into a surface water feature such as a coastal lake, vlei, or an estuary which is closed off from the sea for most of the year, then eutrophication of surface waters and the presence of scum, putrid sediments, disease vectors and aquatic plant infestations are likely to occur in and along the shoreline of the surface water feature (Clark, 1977; Davies and Day, 1986).

All the above factors represent a negative impact on the natural and human environments (Hart and Allanson, 1984). For example, algal scums may cause allergic reactions in bathers and boardsailors, and dense reed growths near the shore may block boat access to deeper waters (Hart and Allanson, 1984). Natural fish species may give way to coarser species with negative effects on recreational angling and on aquatic birds dependent on juveniles of natural fish species for food (Davies and Day, 1986).

A likely long term effect of eutrophication is the gradual build up of organic sediments on the bed of the surface water feature. In extreme cases of eutrophication, life expectancy for a shallow surface water feature may be reduced to a few decades unless costly remedial measures are undertaken (Davies and Day, 1986).

There is a need, therefore, to predict the likely effects of the disposal of septic tank effluent on the human and natural environments from a proposed resort development in order to determine applicable planning constraints and management options for the resort.

3.1.2 The Problem Area

SEWAGE, the prototype specialist system studied in this section, addresses the problem of determining likely effects of septic tank effluent disposal on the human and natural environments.

The determination of likely negative effects of septic tank effluent disposal has been selected as the first problem area to be addressed because the writer has some knowledge of the problem area. It is also considered a useful starting point in order to gain experience in expert systems development (Huntingdon, 1985).

The major goals of this prototype specialist system are to determine :

(1) The likelihood of insufficiently treated effluent surfacing on land, and the aesthetic effects and health hazards that may ensue.

(2) The likelihood of improperly treated effluent reaching a surface water feature, the possible effects of this on eutrophication of surface waters, and thus on aquatic plant life, and the aesthetic effects and health hazards that may ensue.

Other goals are to determine the need for relevant expert advice and alternative sewage disposal options that could be used so as to reduce or eliminate possible negative effects.

Questions relating to the following important aspects are asked:

1) Types of soil cover, based on their permeability and ability to cleanse septic tank effluent.

2) The highest level of groundwater which may be expected over holiday seasons during the year.

3) The density of the residential development.

4) The closest distance between the resort and the boundary of the surface water feature in question.

5) The type of surface water feature considered.

For the purposes of this study, the problem has been addressed broadly. The likely effect of effluent on drinking water supplies is not dealt with. The influence of the ground slope on which the resort is to be situated, and of the flow-direction of the groundwater, is not addressed. The effect of the size of the resort in relation to the size of the surface water feature on the likelihood of an impact occurring, is also not addressed. The likely effects of effluent on rivers, streams, the sea, beaches and well-flushed estuaries are dealt with as a first approximation.

3.1.3 Representation of Knowledge

In the present study, a convenient aid to encoding knowledge into production rules has been found to be in the form of two rule tables, examples of which follow:

Table 3.1 The determination of relationships between answers to key questions and the likely effects of septic tank effluent on the land surface and on groundwater.

IF				THEN	
(a) AND	(b) AND	(c) AND	(d)	(e) AND	(f)
		1	1/2/3	10/10/10	
		2	1/2/3	9/ 8/ 8	9/ 8/ 7
1	1,6,7	5,6,7	1/2/3	5/ 4/ 4	1/ 1/ 1
2,3,4,5	1	4	1/2/3	6/ 5/ 5	4/ 3/ 2
2,3,4,5	6		1/2/3	10/ 9 8	1/ 1/ 1
2,3,4,5	2,3,4,5	5	1/2/3	1/ 1/ 1	7/ 6/ 5
2,3,4,5	2,3,4,7	4	1/2/3	4/ 3/ 2	8/ 7/ 6

The key to columns (a) to (d) and to numbers in them is :

(a) Topsoil type:
- 1 - Clayey
- 2 - Sandy
- 3 - Stony (permeable)
- 4 - Silty
- 5 - Loamy or humic
- 6 - Impermeable bedrock
- 7 - Permeable bedrock
- 8 - Other
- 9 - Unknown

(b) Subsoil type: (same as for topsoil type)

(c) Depth to water table :

- 1 - Above ground
- 2 - Within 0,3 m. of ground surface
- 3 - Greater than or equal to 0,3 m. but less than 2m.
- 4 - Greater than or equal to 2 m. but less than 3 m.
- 5 - Greater than or equal to 3 m. but less than 5 m.
- 6 - Greater than or equal to 5 m. but less than 10 m.
- 7 - Greater than or equal to 10 m.
- 8 - Unknown

(d) Average erf size :

- 1 - Less than 500 sq.m.
- 2 - Greater than or equal to 500 but less than 1000 sq.m.
- 3 - Greater than or equal to 1000 sq.m.

The key to columns (e) and (f) follows:

(e) the likelihood of significant effluent coming to the surface.
(f) represents the likelihood of significant contamination of groundwater by septic tank effluent.

The first four column headings represent the key questions to be asked (qualifiers in EXSYS). Entries in the column under each heading are integer numbers representing possible answers given to the question asked (these answers are equivalent to values in EXSYS). The last two column headings represent the goals which are to be evaluated (choices in EXSYS). Entries in these columns are actual weights given to the goals. The weightings are represented on a scale of 1 to 10 where 1 indicates a negligible likelihood and 10 represents certainty. The rows are constructed to represent patterns of answers for which distinct goal values have been derived.

Blanks left in columns **(a)** to **(d)** indicate that the answer is not important or else not applicable. Blanks left in columns **(e)** and **(f)** indicate that goal values (i.e. weights) are not known or else are not relevant. The sets of values in the last two columns are weights given for average erf sizes represented by **1**, **2** or **3** in column **(d)**. Commas separating the integer numbers in the first three columns represent the disjunctive **OR**.

Table 3.2 The determination of relationships between answers to key questions and the likely effects of septic tank effluent on a surface water feature.

IF				THEN	
(p) AND	(q) AND	(r)		(s) AND	(t)
1,2,5	2	2		4	7
1,2,5	6	2		1	5
3	2	3		8	10
3	5	3		5	10
6	5	3		4	8
4,9	4	3		7	10

The key to columns (p) to (r) and to numbers in them is:

(p) Water feature type :

1 - Ephemeral stream or river
2 - Perennial stream or river
3 - Coastal lake
4 - Vlei
5 - Estuary: open to the sea all year
6 - Estuary: open to the sea for most of the year
7 - Estuary: open to the sea seasonally only
8 - Estuary: open to the sea occasionally
9 - Stagnant portion of an estuary
10- Other

(q) Shortest distance between the proposed development and the surface water feature is:

1 - less than 10 m.
2 - greater than or equal to 10 m. but less than 30 m.
3 - greater than or equal to 30 m. but less than 50 m.
4 - greater than or equal to 50 m. but less than 100 m.
5 - greater than or equal to 100 m. but less than 300m.
6 - greater than or equal to 300 m.

(r) Likelihood of significant contamination of groundwater:
1 - less than 5
2 - greater than or equal to 5 but less than 7
3 - greater than or equal to 8 but less than 10
4 - 10

The key to columns (s) and (t) follows:

(s) represents the likelihood of significant eutrophication of portions of the surface water feature occurring.
(t) represents the likelihood of further expert advice being needed.

The first two column headings represent the key questions to be asked. Entries in the column under each heading represent possible answers given to the question asked. The third column contains entries which represent weights from column (f) in table (1), whereas the last two column headings represent goals which are to be evaluated. As before, entries in these columns are actual weights given to the goals, where weightings are represented on a scale of 1 to 10.

The last two goal values in each row are dependent on answers to two key questions (in columns (p) and (q) as well as on a previously evaluated goal (in column (r)), the latter three being represented by integer numbers. As

before, the rows are constructed to represent patterns of data for which distinct goal values have been derived.

The reason why two rule tables have been drawn up in place of one is because one goal is needed in order to determine the value of another, and further key issues required for the determination of the latter goal are not the same as for the former. This issue is discussed further in section 3.1.4.

A rule table is a useful aid in the formulation of rules for problems of the type addressed in this section. Knowledge gaps and redundant information are easily identified. Furthermore, it is possible to see where two or more rules should be used in place of one, or vice-versa. An example of a rule drawn up from the bottom row in table 3.1 and one from the bottom row in table 3.2 is given as rule (1) and rule (2) in section 3.1.4.

The approach used for this problem has some similarities to that used by Lehmer and Barth (1985, p.204) and Quinlan (1982, p.196) for classifying knowledge prior to the formulation of rules.

Munn (1979, p.68) discusses identification and categorization of variables and the use of "interaction tables" in the context of carrying out environmental assessments. This bears many similarities to problem-solving methods discussed in this study (see also sections 3.3, 3.4 and 2.8).

3.1.4 When One Goal is Needed in Order to Determine the Value of Another

In order to address the possibility of groundwater being contaminated by septic tank effluent, applicable rules address the goal (or choice in EXSYS): "Contamination of groundwater by septic tank effluent is likely."however, the likelihood of a surface water feature being contaminated by septic tank effluent is partially dependent on the groundwater in the immediate vicinity being so contaminated, and the problem arises of the value of one goal being needed

in order to determine the value of another. The expert system building tool, EXSYS, caters for this by delaying the evaluation of goals dependent on other goals until near the end of the consultation. Rules have been drawn up to link the two goals, incorporating preconditions such as the distance of the resort development away from the relevant surface water feature boundary. An example of two such rules derived from Tables 3.1 and 3.2 in section 3.1.3 follow :

Rule 1

	QUALIFIERS	VALUES	
	IF		
Precondition (1)	sewage disposal is	by septic tank by soakage pit	or
	AND		
Precondition (2)	surface soil is	sandy stony silty loamy	or or or
	AND		
Precondition (3)	subsoil is	sandy stony silty permeable bedrock	or or or
	AND		
Precondition (4)	average erf size is	less than 500 sq m.	
	AND		
Precondition (5)	the highest seasonal level of groundwater table is	between 2m and 3m of the surface	
	CHOICES	WEIGHTINGS	
	THEN		
Choice (1)	groundwater is likely to be contaminated by improperly treated septic tank effluent	8/10	
	AND		
Choice (2)	septic tank effluent could come to the surface, resulting in the presence of scum, bad odours and disease vectors (and more) in certain locations such	4/10	

as dips, hollows and seepage areas

AND

Choice (3) consider alternative means of sewage disposal 7/10

AND

Choice (4) (contact specialists) ...

AND

Choice (5) (advice) ...

NOTE .. (Reason for this rule) ...

REFERENCE .. (Source of information)

Rule 2

	QUALIFIERS	VALUES
	IF	
Precondition (1)	the relevant surface water feature is	a vlei or a stagnant portion of an estuary or coastal lake
	AND	
Precondition (2)	the shortest distance between the water feature boundary and the boundary of the proposed development is	between 50 m and 100 m
	AND	
Precondition (1)	the likelihood of groundwater being contaminated by improperly treated septic tank effluent is	greater than 7/10

	CHOICES	WEIGHTINGS
	THEN	
Choice (1)	eutrophication of surface waters, and the presence of scum, putrid sediments, disease vectors, and aquatic plant infestations (usually of one or two species)	7/10

	could result in, and along the shores of, the surface water feature in question	
	AND	
Choice (2)	consider alternative measures to reduce the likelihood of the problem occurring (alternative sewage disposal options, amongst others)	10/10
	AND	
Choice (3)	contact specialists such as limnologists, hydrologists and geologists for further advice on the possibility of significant eutrophication occurring. See references.	10/10
	AND	
Choice (4)	(advice such as possible mitigating measures)	
	NOTE (reason for this rule)	
	REFERENCE (source of information for this rule)	

Considering the above example, if the first rule is executed and preconditions (2) and (3) in the second rule are met, then the second rule will also be executed and the choices in both rules are then considered valid.

3.1.5 Testing the specialist prototype system

The prototype system has been tested on a resort development proposal already assessed by government officials aided by specialists. The proposed development was considered to have potential septic tank effluent disposal problems. The computed results agreed closely with those officially determined for the development proposal. However, although giving an acceptable answer in this case, if the resort proposal plans had catered for more erven, the likelihood of an impact may have been officially considered higher than that predicted by the prototype system. This is because the

latter caters for development density, but not size in relation to the surface water feature. A further potential problem (discussed in Section 2.6.2) is that when more than one rule applies (working in parallel) the average of the weights is taken as the final weight. This value is likely to be too low. Finally, weightings are only roughly estimated in the prototype specialist system.

3.1.6 Suggested Improvements

Significant improvements to the quality of the performance of the prototype specialist system are likely to occur if the following changes are made :

1) Refine the categories (for example, where two rules in place of one would bring about a significant increase in accuracy of the solution, use two rules).

2) Add more preconditions to the rules to account for the size of the resort and the size of the surface water feature. This means expanding the number of rules required.

3) Further rules could be added to aid in establishing certain information, if this is unknown. For example, the determination of likely groundwater levels by using information gained from soil tests and that gained from observing certain types of plants growing in the area.

4) If there is already evidence of septic tank disposal problems in the area, rules capable of using this information could be included, as could rules on special options for disposal of septic tank effluent, such as by special reed bed treatment, a marine pipeline to sea, and others.

5) If the current expert system building tool is to be used, then to prevent the possibility of more than one rule evaluating the same goal, rules should be constructed so that a set of single-valued answers

to the key questions will cause a goal to be evaluated by not more than one rule.

3.1.7 Conclusion

The study indicates that expertise in the area of septic tank waste disposal can be suitably modelled by an expert systems approach in order to predict the likely effects of septic tank effluent disposal at a proposed resort on the human and natural environment.

3.2 PHYSREC: The Physical Recreation Carrying Capacity Model

3.2.1 Introduction.

The assessment of the recreational carrying capacity of a surface water feature is considered to be a necessary input for determining the size and kind of recreational resort development which may be allowed on land adjacent to the feature. A prior assumption is that recreational pressure on the feature during holiday periods is directly proportional to the amount of holiday accommodation available in the vicinity (Sowman and Fuggle, 1986). In other words, as more holiday accommodation is made available to holiday makers, so more people will be attracted to make use of accessible recreational resources in the area. If the increase in available holiday accommodation continues, the recreational pressure on the surface water feature can reach levels where significant environmental degradation to the feature and its environs may result (Wall and Wright, 1977). This aspect, as well as overcrowding itself, reduces the quality of the recreational experience for many.

In order to prevent overcrowding of a surface water feature or else to reduce it to more acceptable levels, several management or planning options (or constraints) could be applied, inter alia:

(1) More recreational facilities, such as a tidal pool or a boat ramp to the sea, may be built nearby.

(2) Further resort development in the vicinity may be strictly limited (Sowman and Fuggle, 1986).

(3) Restrictions on type and intensity of recreational use on a sensitive area may be imposed (Wall and Wright, 1977).

PHYSREC, the prototype specialist expert system studied in this section, addresses the problem of determining the

likelihood of exceeding the physical recreation carrying capacity for craft on a body of water at current and possible future peak holiday use levels. The possible future peak holiday levels are considered to depend upon further development of holiday accommodation in the area. This could be when either all currently available erven are fully developed and no more erven are allowed in the area or when all erven, including those in current development proposal plans, are fully developed.

3.2.2 The Problem Area

In order to address the problem stated above, certain provisos are required:

(1) There needs to be an area of water of limited size and of suitable depth in the vicinity.

(2) There should already be some holiday resort development in the area, and resident holiday-makers should currently be making recreational use of the water surface in question.

Recreational use considered in the present study is limited to powerboating, yachting and boardsailing, either separately or in any combination of the three. Although powerboating activities usually involve skiing this was not considered separately in the study. The space requirements for skiing as well as those for other types of powerboating activity were taken as an average of four hectares per activity (Sowman and Fuggle, 1986, p. 67). The average space requirements for yachting is half a hectare per activity and for boardsailing, one tenth of a hectare per activity (Sowman and Fuggle, 1986, p 68)

This problem was selected for the present study because:

(1) It incorporates a social aspect in the assessment of development proposals which may be easily overlooked, yet is important.

(2) It involves a different form of expertise compared with the other problem areas addressed in the study.

(3) The answers to the problem area affect, and are affected by, the answers to others.

(4) Suitable expertise is available in the form of published literature.

(5) The present topic ties in readily with the subject of the third specialist problem area addressed, namely, the selection of suitable recreation management options for the three types of craft concerned.

3.2.3 Source of Expertise

The source of expertise used for the present task is the article by Sowman and Fuggle (1987): A Case Study of the Kromme River Estuary, South Africa. The paper describes, *inter alia*, a procedure for assessing the physical carrying capacity of a body of water used by powerboats, yachts and sailboards during peak holiday periods.

3.2.4 Goals of PHYSREC

The goals (or objectives) of PHYSREC are:

(1) Determine if the surface water area in question is of sufficient depth and size to accommodate at least one boating activity of each type.

(2) Estimate the likelihood of the physical recreation carrying capacity being exceeded:

  (a) at current peak holiday levels.

  (b) when all the presently available erven are fully developed.

(c) when all erven, including those in resort development proposal plans, are fully developed.

3.2.5 Important Questions

The key questions needing to be addressed are:

(1) What is the size of the available surface water area which is of sufficient depth for the boating activity concerned?

(2) How many craft of each different type currently make use of the area during peak periods in high holiday season?

(3) What is the proportionate increase in holiday accommodation likely to be when all presently available erven are developed?

(4) What is the proportionate increase in holiday acocmmodation likely to be when all erven, including those proposed in relevant resort development proposal plans, are developed?

3.2.6 A Suggested Problem-Solving Approach

The solution to the type of problem presented in this section appears to be best effected by representing the knowledge in a semi-procedural form. This was neccessitated by the fact that formulae or algorithms need to be included with expert knowledge in order to derive an acceptable solution.

An attempt was originally made to determine the likelihood of the physical recreation carrying capacity being exceeded by comparing the number of a specific type of craft using a water surface area with the number required to equal its physical recreation carrying capacity. Encoding this knowledge using production rules promised to be labour intensive and cumbersome and so this approach was abandoned. Another approach to solving this type of problem is

apparent. This approach involves the use of the concept of a "congestion factor" (denoted by the symbol CF for the purposes of this study) which is used in an attempt to rationalize (or formalize) the solution procedure.

3.2.6.1 The Physical Recreation Congestion Factor

In order to show how the adopted procedure attempts to solve the type of problem presented, the concept of physical recreation carrying capacity is examined first:

The physical recreation carrying capacity for a body of water which is used for one type of craft activity may be defined as the numeric value:

> [the water surface area available for use]
> DIVIDED BY
> [the recommended space standard for the boating activity concerned].

This is the recommended upper limit for the number of individual activities able to be safely and efficiently accommodated on the water surface area in question (Sowman and Fuggle, 1986).

The physical recreation congestion factor (CF) is related to the carrying capacity by the following formula:

> CF = [number of active craft]
> DIVIDED BY
> [carrying capacity for the craft in question]

From the above formula, it may be seen that CF is a measure of the intensity of recreational use of a specific water surface area. Thus when it is less than unity, the recreational use intensity is less than the physical carrying capacity, and when CF is greater than unity, the use intensity is greater than the physical carrying capacity. However, this assumes that CF is precisely evaluated.

For the purposes of this study, the congestion factor for one type of craft using a water surface area could be determined according to the formula:

CF = [number of active craft]
MULTIPLIED BY
[recommended space standard]
DIVIDED BY
[water surface area available for use]

In order to accommodate use by more than one type of activity on a body of water at the same time, this form of the congestion factor may be generalized to:

CF = [the minimum area required by the craft]
DIVIDED BY
[the actual area available for use]

Where the minimum area required by the craft is calculated as the sum over the activity types of:

[the number of active craft of each type]
MULTIPLIED BY
[the recommended space standard per activity type]

A problem is that the congestion factor is not a precise measurement, primarily because it is dependent on a recommended space standard for each craft activity in question, and this standard is only approximately ascertained. In order to encode the information into production rules it is convenient to consider knowledge in a form which takes into account the imprecise nature of CF. Thus, instead of statements such as: "When CF is greater than unity, the physical recreation carrying capacity is exceeded.", it is more meaningful to say: "The larger the value of CF, the more likely it is that the physical carrying capacity will be exceeded". This is a key concept in the present modelling exercise.

In order to determine the likelihood of the carrying capacity being exceeded at current and possible future levels of use, rules are drawn up which relate this likelihood to the estimated magnitude of the congestion factor at those levels of use. An example of such a production rule is:

IF CF is greater than 2 AND CF is less than 2,5 THEN it is likely, (8/10), that the physical carrying capacity will be exceeded.

CF, however, needs to be calculated from a formula, and it is therefore important that the production system building tool can incorporate formulae into the rules. Formulae incorporated into PHYSREC include the congestion factor formula as well as formulae for calculating the proportionate increase in peak holiday population levels. (See rule numbers 21 and 24 in appendix V)

3.2.6.2 The Use of Formulae in PHYSREC

The congestion factor formula, as well as formulae for calculating the proportionate increase in peak holiday population levels, facilitates use of the specialist system in a "trial and error" estimation process. The congestion factor formulation, for example, allows any of three (or more) variables to be conveniently changed so as to gauge the effect that the change has on the congestion factor, and so aids in the determination of suitable values for the variables concerned. This is especially useful when considering management options such as temporal or spatial zoning, the possible prohibition of certain recreational activities, and restriction on total craft numbers.

An example of the usefulness of the above-mentioned formulae in a trial-and-error estimation process follows:

Suppose that powerboats, yachts and sailboards use a certain area of water, and that a resort development is proposed in the vicinity. Suppose the congestion factor is estimated to be 2.0 for this situation. It may then be inferred that the physical recreation carrying capacity is very likely to be exceeded. The decision maker (or user) could then suggest reducing the size of the township by half (reasoning by default and then, later on, changing this assumption) and the program could then be run again to determine the effect this change might have on the likelihood of exceeding the aforementioned carrying capacity.

Alternatively, it might be known that powerboats are likely to cause a severe impact to breeding colonies of an aquatic bird species during the period in question. Then by

prohibiting powered craft from using the area in question, the threat to the breeding bird colonies is reduced and an added benefit is that the recalculated congestion factor is smaller, thus making it less likely that the carrying capacity will be exceeded. If the overall management priority for the area is for conservation, then this may be an important move toward an acceptable solution.

3.2.6.3 Estimation of the Proportionate Increase in Possible Future Holiday Population Levels

In order to estimate a possible future physical recreation use intensity on a limited area of water, it may be assumed that recreational pressure is proportional to the number of holiday-makers in the vicinity, and that the latter is proportional to the amount of holiday accommodation in the area (see section 3.2.1). If the current peak holiday recreational pressure is known, then the proportional increase in pressure at some point in the future may be estimated to be the same as the proportional increase in the amount of holiday accommodation in the area, and so the peak holiday recreational pressure may be estimated at that future point.

The procedure used for the present study is as follows:

(1) Determine the current number of single residential erven with houses on them (Eh) and those without houses on them (Ev);

(2) Count the number of single-residential erven on resort development proposal plans (Ep);

(3) Estimate the average number of occupants per house during peak holiday season. The default value for this is about 6,5 (Sowman and Fuggle, 1976);

(4) Calculate the peak holiday population living on single residential erven;

(a) Currently: (Eh * 6,5);

(b) At a time when all presently available erven are developed:((Eh + Ev) * 6.5);

(c) At a time when all erven, including those in current development proposal plans, are developed: ((Eh + Ev + Ep)* 6,5);

(5) In a similar way, calculate peak holiday population figures for other types of accommodation;

(6) Calculate the total peak holiday population figures for all types of accommodation for the current (Pc) and the two possible future peak holiday levels (Pl and Ph).

(7) Calculate the values **LOW PROPORTION** (Pl/Pc) and **HIGH PROPORTION** (Ph/Pc).

Then **LOW PROPORTION** gives a rough estimate of the likely increase in recreational pressure of the water surface area in question when all presently available erven are developed, and no further development plans are approved. **HIGH PROPORTION** gives a rough estimate of the likely increase in the recreational pressure of the water surface area in question when all erven, including those on resort development proposal plans, are fully developed.

(8) The final step is to multiply **CF**, the physical recreation congestion factor for the water surface area in question during current peak holiday periods, by the numeric values **LOW PROPORTION** and **HIGH PROPORTION**. The results are estimates of the congestion factors for the two future cases considered.

3.2.7 Testing PHYSREC

On carrying out trial runs it was found that PHYSREC provided no answers for low values of **CF**. These are values of **CF** for which it is unlikely that the physical recreation carrying capacity is exceeded. In order to incorporate these low values, a few "catch-all" rules were drawn up. These rules are to inform the user that the carrying capacity is

unlikely to be exceeded. (See rule number 25 in Appendix V (PHYSREC)).

A test has been carried out using a case study on the Kromme River Estuary, South Africa, where proposed resort development is considered likely to cause overcrowding of natural recreational resources in the vicinity (Sowman and Fuggle, 1986). Results from the test confirm that the physical recreation carrying capacity of the estuary is likely to be exceeded for powerboating when all erven, including those proposed in development plans, are developed.

3.2.8 Suggested Improvements

(1) Subdivide the recreational categories further, for example:

   (a) powerboats with skiers, powerboats on their own at speed and powerboats cruising on their own

   (b) large yachts and small yachts

   (c) sailboards

   Space requirements for these categories are given in the literature (Sowman and Fuggle, 1986)

(2) Increase the number of rules which relate the congestion factor to the likelihood of exceeding the physical recreation carrying capacity.

(3) Refer the user to other sources of expertise (see 3.3.6.1 for more details).

3.2.9 Conclusion

From the present study, the benefits of using formulae together with heuristic knowledge in a production system are seen to be a reduction in system size, improved system-response time and greater precision in the results. A major benefit is the effectiveness of using the production system in a "trial-and-error" estimation procedure such as that employed in the prototype knowledge-based consultation system addressed later in the study (see section 3.4.6). The study indicates that an expert systems approach may be suitably used to determine the likelihood of exceeding the physical recreation carrying capacity for craft on a body of water at current and possible future levels of use.

3.3 AVIREC: Model for Determining Recreation Management Options.

3.3.1 Introduction

Many aquatic bird populations are disturbed and their habitats threatened by recreational activities and indiscriminate township development taking place at or near water surface features along the South African coastline (Rowlands, 1984; Ryan et. al., 1986). There is a need, therefore, to plan and to manage these activities in a way which will be compatible with conservation principles for birds and their habitats.

Published data on the effect of different water-related recreational activities on aquatic bird populations is scarce (Rowlands, 1984). The effective utilization of existing expertise, along with available published data, is needed for management and planning purposes (Davis and Nanninga, 1985).

3.3.2 The Problem Area

AVIREC, the prototype specialist system studied in this section, addresses the problem of determining recreational management options for craft using a surface water feature which is also used by birds for foraging, roosting and breeding. A further problem addressed is the likelihood of the feature being an important habitat for birds.

This problem area has been selected to be modelled for the following reasons:

(1) There is a need for effective utilisation of existing expertise (Starfield and Bleloch, 1986; Rowlands, 1984).

(2) This problem area is dependent on the solutions to the other problem areas modelled.

(3) Enthusiastic aquatic bird experts have been close at hand during the course of the study.

(4) Avifauna are considered an important component of wetland ecosystems (Rowlands, 1984; Ryan *et al*, 1986).

(5) This specialist problem domain is of a different type and involves different disciplines to the other two modelled.

For the purposes of this study, three recreational boating activities which have an impact on aquatic birds are selected: powerboating, boardsailing and yachting. The species of bird selected are known to be highly sensitive to different aspects of boating activities such as noise, physical disturbance, visual impact and, to a possibly lesser extent, pollution and sediment suspension. One species, the Caspian Tern, is very sensitive to most types of disturbance, and particularly so while roosting or breeding. It is also considered to be rare in South Africa (Brooke, 1984), and so is an ideal candidate for modelling purposes. Other birds addressed are Red-Knobbed Coot and Darter. The geographical area of concern is limited to the coastal zone of the south-western Cape Province.

3.3.3 Sources of Expertise

Sources of expertise used for the present task:

(1) An unpublished M.Sc. thesis entitled: "The Effects of Recreational Activities on Aquatic Avifauna" by Rowlands (1984).

(2) Ornithologists at The Percy Fitzpatrick Institute, University of Cape Town, Cape Town.

(3) Bird experts at The Department of Environmental and Geographical Science, University of Cape Town, Cape Town.

(4) A bird expert from the Sea Fisheries Research Institute, Department of Environment Affairs, Cape Town.

3.3.4 Goals of AVIREC

A major goal of the prototype specialist system studied in this section is to determine management options which will considerably reduce the disturbing effects of different boating activities on aquatic birds, whether individual species or populations, which inhabit a surface water feature. A secondary goal is to estimate the likelihood of the surface water feature (and its environs) being an important habitat for the birds in question. A further goal is to alert the user to relevant sources of expertise.

3.3.5 Important Issues

The determination of management options for recreational activities on a surface water feature which is used by birds is perceived to be mainly dependent on:

(1) The sensitivity of each bird species to different types of recreational disturbance (Rowlands, 1984; de Roos, 1981; Hockey, 1987, pers.comm.).

(2) The effects that each recreational activity might have on the bird habitat, including type and intensity of recreational use and the period concerned (Brooke, 1984; Rowlands, 1984; Hockey, 1987, pers. comm.).

(3) The type of use that the birds make, and the season (or period) concerned (Brooke, 1984; Taylor, 1987, pers. comm.; Rowlands, 1987 pers. comm.).

(4) The conservation-worthy status of bird species, bird populations and their habitat (Brooke, 1984).

(5) The presence of alternative bird refuges in the vicinity (Ryan *et al*, 1986; Hockey, 1987, pers. comm.).

(6) The availability of alternative bodies of water in the vicinity, with potential to accommodate the boating activity concerned, and the availability of alternative recreational resources.

(7) The overall management priorities for the area (Davis and Nanninga,1985 ; Starfield and Bleloch, 1983).

In order to determine the likelihood of the surface water feature being an important habitat for aquatic birds, important issues are seen to be dependent on:

(1) The sensitivity of each bird species to disturbance (Rowlands, 1984; de Roos, 1981; Hockey, 1987, pers.comm.).

(2) The type of use that birds make of the surface water feature (Brooke, 1984; Taylor, 1987, pers. comm.; Rowlands, 1987, pers. comm.).

(3) The conservation-worthy status of bird species and populations making use of the surface water feature(Brooke, 1984).

(4) The presence of alternative bird refuges in the vicinity (Ryan *et al*, 1986; Hockey, 1987, pers. comm.).

(5) The surface area of marshland (Ryan *et al*, 1986).

(6) Habitat diversity and naturalness (Ryan *et al*, 1986; Fuggle and Rabie, 1983, p.218).

(7) Bank steepness, presence of mudflats and saltmarshes, threat of human disturbance and others (Ryan et al,1986; Fuggle and Rabie, 1983; Brooke, 1984; Berruti, 1987, pers. comm.).

3.3.6 Special Problems

3.3.6.1 The Need for More Information

In this specialist expert system, the problem of what to do when more information is needed, is addressed. Several approaches have been considered:

(1) Where insufficient information is available, or conflicting potential solutions to the problem exist, or decisions involve high risk, extra advice may be needed. There is a need to direct the user to the relevant sources(s) of advice or expertise. For large expert systems, these could be located in special reference files containing names, addresses and library references and used by the expert system when needed. In this system, expert addresses and book references form part of the final conslusions in some of the rules. (See Appendix VI: Rule Nos. 13 & 19).

(2) When insufficient information is available, or when the user does not know the answer to a question, several approaches may be considered:

(a) The first is where an assumption is made which can be retracted during the consultation as further evidence becomes available. A way of doing this is to take an intelligent guess and then return at a later stage to refine it using information generated (see Sect. 3.4.5). This is basically a "trial-and-error" procedure which uses the notion of "feedback" in a system.

(b) A second approach is one which involves "reasoning by default" in which a value which is true in most of the cases is used. This value may be taken from a special data file. The data in the file may have been placed there by another computer program, or a software package such as a geographic information system, amongst others. The default value may be presented to the user for approval before the consultation continues. Default values cater for the reasoning approach: "Unless there is evidence to the contrary, assume the fact

to be true" (Hayes-Roth *et al*, 1983; Rich, 1983).

(c) A third approach to this problem, and that used in this prototype model, is one in which the user may not be sure of the information required. The expert system then branches away from its current reasoning procedure, and follows another in order to gather data to supply the information required. This information is then presented to the user for approval or for selection from amongst likely choices. The consultation may then be continued.

For example, suppose the user, on being asked the question on what Caspian Tern *(Hydroprogne caspia)* are doing in the area in question, replies with "Caspian Tern are roosting, but it is not known whether they are breeding". The prototype specialist system then asks questions so as to gather other information which it uses so as to supply the likely answer (See Appendix VI: rule number 24). The expert system does this by asking questions on the geographic location and the season. By combining this information with what it already knows, it concludes with the likelihood of the birds breeding. The addresses of bird specialists are also given so that further advice may be obtained by the user if needed.

(d) A fourth approach is one in which the expert system may temporarily halt its current reasoning procedure to call up another specialist expert system so as to obtain the needed data before continuing. For example, if a habitat diversity index is needed so as to help determine the conservation potential of a surface water

feature, then a suitable specialist expert system could be called (or consulted) by the current one so as to obtain the required data. This approach is potentially suitable for this system and is catered for (see Appendix VI: rule numbers 50 & 51), but has not been used due to the non-availability of a suitable prototype specialist system.

3.3.6.2 Scaling Effects

The current prototype specialist system is able to address only a very small task in what appears to be a large problem domain. When developing a working model based on this system, a problem that is likely to arise is that of a scaling effect. A scaling effect occurs when the average time a consultation takes increases at a rate far greater than the proportional increase in the size of the system. For large systems, this can result in very long waiting times (Rich, 1983; Winston, 1977). The main reason for this is that every rule in the rule file must be tested for applicability, even though the rule may have no bearing on the task at hand (Hayes-Roth, 1985). For large rule files a significant amount of time may be wasted in this process.

According to Pau (1986), Winston (1977), Rich (1983) and Alty and Coombs (1984), the recommended way around this problem is to partition the rules into groups so that each group of rules represents knowledge which is applicable in a specific context. The expert system must then be able to address a designated group when its contextual knowledge holds true (See Appendix II for further details on contextual knowledge).

In a full-scale specialist expert system, partitioning of rules could be profitably based on the type of use that birds make of a surface water feature, as well as on the type of surface water feature itself. Another possibility includes a further partitioning according to geographic area. For example, if there are several species of bird

which are known to breed along the shoreline of coastal lakes and estuaries in the south-western Cape Province during the summer holiday season, then these birds are all likely to be sensitive to wave set-up from powered craft being used over that period, in the vicinity of their nests. Thus similar management options should apply to the different species in this situation, and the same rules could be applied for different species of bird, with different weighting factors applied to each species.

Separation of different kinds of knowledge into separate expert systems (Pau, 1986) may be feasible when considering other forms of recreational pressure on a surface water feature and its environs. Examples of recreational activities requiring different kinds of knowledge are angling, bait collecting and swimming.

3.3.7 Representation of Knowledge

All the expertise gathered for the present task is able to be conveniently represented as "rule tables". An abridged version of one follows:

Table 3.3 The determination of relationships between answers to key questions and various goal values: If (a) AND (b) AND (c) AND (d) AND (e) AND (f) THEN (g) AND (h) AND (i) AND (j) AND (k) AND (l)

IF						THEN					
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	1	3		N/A	2,3				9	N/A	10
1	1	1	2	N/A	N/A	10				N/A	9
3	1	2	3	N/A	N/A	9		10		N/A	9
	1	3	1	1	N/A	N/A	N/A	N/A		5	9
2	2		1	N/A	N/A		2			N/A	2
2	2		3	N/A	N/A		10		7	N/A	9
	1	3	3	13*	2,3	N/A	N/A	N/A		9	10
1	1	2	2	N/A	3	8		8		N/A	10

(Note: 13 should read: 13,1,2,3,4 where "," denotes "OR")*

The key to columns (a) to (f) and the numbers appearing in them is:

(a) Type of recreation:
1- Powerboating
2- Yachting
3- Boardsailing

(b) Name of the bird species in question:
1- Caspian Tern *(Hydroprogne caspia)*
2- Darter *(Anhinga melanogaster)*
3- Red-Knobbed Coot *(Fulica cristata)*

(c) Type of use made by the birds in question:
1- Breeding
2- Roosting but not breeding
3- Roosting but not known if breeding
4- Foraging or other

(d) Number of individual birds present:
1- One or two
2- Several
3- Many

(e) Period in question:

1- January	9- September
2- February	10- October
3- March	11- November
4- April	12- December
5- May	13- Summer
6- June	14- Autumn
7- July	15- Winter
8- August	16- Spring

(f) The value of the area as a habitat for the birds in question is:
1- high (i.e. important)
2- low (i.e. unimportant)
3- unknown (of unknown importance)

(Note: See section 3.3.9 for comments with regard to the relevance of this question in AVIREC.)

Entries in columns **(g)** to **(l)** are weightings indicating the importance of management options or advice or else a likelihood of a statement being true. Column headings are as follows:

(g) Prohibit the craft in question in the area over the period concerned

(h) Limit the numbers of craft in question

(i) Apply speed limits to the craft in question

(j) The area is an important habitat for the birds concerned

(K) The bird in question is breeding

(l) Obtain extra advice from bird specialists

Columns (a) to (f) represent the possible answers to important questions. Columns (g) to (l) represent the goals (choices in EXSYS) to be evaluated. Entries in these columns are actual values (i.e. weightings) given to the goals.

Blank spaces appearing in the table indicate that the values are unknown or are not important. The symbol N/A indicates that the values concerned are not applicable.

Rules whose preconditions and conclusions (goals) are reflected in the last two rows of Table 3.2 are rules 24 and 34 in Appendix VI

3.3.8 Testing Avirec

Trial runs have been undertaken in conjunction with bird specialists and improvements to AVIREC have been made as a result of their suggestions. There is a general feeling amongst the specialists concerned that an expert systems approach is a feasible one to use in developing a decision support system for conservation purposes. However, reservations have been expressed with regard to memory requirements and speed of processing for a full-scale specialist system (this aspect is discussed under scaling effects- see sub-section 3.3.6.2)

3.3.9 Suggested Improvements

Whether a surface water feature already has some conservation-worthy status was first considered at first to be a central issue for the goals selected. However, this information has very little effect on these goals and it is now believed to be information better used at a higher level by the coordinator (see section 3.4.3).

Also, the system is incomplete when determining the likely importance of the surface water feature as a habitat for birds. This is mainly due to the need for this system to gain information on the habitat (such as a diversity index) from an outside source, preferably another specialist system. The latter is not at present available, but should be included in a full-scale knowledge-based consultation system.

Further, in spite of the relatively large number of rules constructed, often two or more answers to several questions had to be included in a rule due to constraints on available time. Significant improvements to the accuracy of system performance should result from refinement of these rules.

3.3.10 Conclusion

In spite of the primitiveness of the prototype specialist system, AVIREC, there is an indication that the expertise required in determining recreational management options for a surface water feature used by birds may be suitably modelled using an expert systems approach.

3.4 The Coordination of the Specialist Expert Systems: SEWAGE, PHYSREC and AVIREC

3.4.1 Introduction

In order to address problems of a multi-disciplinary nature there is usually a need to have access to different forms of expertise. There is also a need to work with this expertise in a holistic context in order to obtain acceptable solutions to problems (Munn, 1979, p66).

GENREC, the prototype generalist expert system (or co-ordinator) outlined in this section, is designed to assimilate expert information and advice from SEWAGE, PHYSREC and AVIREC. It is also designed to make use of more general information (in this case, management priorities for the area) so as to determine one or more suitable approaches towards deriving applicable constraints for coastal resort development proposals. GENREC can also recommend practical measures and give advice.

3.4.2 Objectives of GENREC

The major objective of GENREC is to generate acceptable solutions to coastal zone resort development proposals. The aim is to reduce the likelihood of significant adverse impacts and to accomodate management options such as those that might be recommended by AVIREC.

An example of a goal which may accord with such an objective is:

> Reduce the total number of erven proposed, then re-determine the likelihood of significant eutrophication occurring in the surface water feature, as well as the likelihood of exceeding the physical recreation carrying capacity for craft when all erven, including those proposed, are fully developed.

A second objective is to determine practical measures which may help to reduce the likelihood of significant negative impacts occurring. For example: investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, dips and mounds) and corridors (e.g. pathways, raised boardwalks, roads) in order to direct specific recreational activities away from the area concerned.

A third objective is for GENREC to control the consultation process by calling up each specialist expert system when the need for it arises and for information to be successfully passed between them. This has not been incorporated into the current prototype model for reasons discussed in section 3.4.6.

3.4.3 Specific Information Used by GENREC

Data required by GENREC from SEWAGE, PHYSREC and AVIREC and from the user in order to generate applicable constraints to coastal resort development proposals and to give certain recommendations is as follows:

(1) The likelihood of significant eutrophication occurring in the surface water feature as a result of improperly treated septic tank effluent entering it via groundwater seepage (this value is obtained from SEWAGE).

(2) The product of the physical recreation congestion factor, CF, and the ratio **HIGH PROPORTION** (obtained from PHYSREC).

(3) The weighting given to the management option: "Prohibit powerboats from using the area in question" (obtained from AVIREC).

(4) The likelihood of the surface water feature being important for birds (obtained from AVIREC).

(5) The management priority for the area (whether it is towards conservation or recreation).

(6) The type of boating recreation considered for the water surface area.

3.4.4 Representation of Knowledge

The knowledge needed by GENREC for the present study is able to be conveniently represented in the form of rule tables. The unabridged tables follow:

Table 3.4: The determination of relationships between combinations of key issues and goal values: Suitable approaches to determining applicable constraints for coastal resort development proposals: IF (b) AND (c) AND (d) AND (e) AND (g) THEN (o) AND (p) AND (q) AND (r) AND (s) AND (t)

	IF					THEN					
(a)	(b)	(c)	(d)	(e)	(g)	(o)	(p)	(q)	(r)	(s)	(t)
1	1	1	1	1	1	7					
2	2	1		1						5	
3	3	1		1						7	
4	1	1	1	2	1	5					
5	2	1		2			8			7	
6	3	1		2			8			9	
7	2	2	1	2				4	8		
8	3	2	1	1				4	9		
9	1	2	1	2				7			6
10	2	2	1	1				4	8		
11	1	2	1	1				6			6
12	3	2	1	2				5	9		

Table 3.5: The determination of relationships between combinations of key issues and goal values: Suitable approaches to determining applicable constraints for coastal resort development proposals: IF (c) AND (d) AND (e) AND (f) AND (g) THEN (m) AND (n) AND (q) AND (u) AND (v) AND (w) AND (x)

	IF					THEN						
(a)	(c)	(d)	(e)	(f)	(g)	(m)	(n)	(q)	(u)	(v)	(w)	(x)
13	1	2	1	1					7		8	6
14	1	2	2	1					8		8	7
15	2	1	2					8	8	8	8	7
16	2	2	2	1				8	9	9	9	8
17	2	1	1					7	7	8	8	5
18	2	2	1	1				7	8	8	7	6
19	3		1					9	9	10	10	8
20	3		2					10	10	10	10	9
21	4		2									10
22	4		1					10	10			9
23			1	1	2	6						
24			1	3	2		3					
25			2	1	2	8						
26			2	3	2		5					
27			1	1	3	8						
28			1	3	3		5					
29			2	1	3	10						9
30			2	3	3		7					9
31				1	4	10						
32				3	4		9					

The key to columns (a) to (g) and the numbers appearing in them follows:

(a) The rule number.

(b) The likelihood of eutrophication occurring in the surface water feature on a scale of 1 to 10, as obtained from SEWAGE:

1- Less than 5
2- Greater than or equal to 5, but less than 8
3- Greater than or equal to 8

(c) The product of the physical recreation congestion factor, CF, and the ratio HIGH PROPORTION, as obtained from PHYSREC:

1- All values less than 1
2- All values greater than 1
3- All values greater than 2
4- All values greater than 3

(d) The weighting given to the management option: "Prohibit powerboats from using the area in question " on a scale of 1 to 10 as obtained from AVIREC:

1- Less than 5
2- Greater than or equal to 5, but less than 8
3- Greater than or equal to 8

(e) The management priority for the area:

1- Towards recreation
2- Towards conservation

(f) The type of recreation considered for the surface water area in question:

1- Powerboating
2- Yachting
3- Boardsailing

(g) The likelihood of the surface water feature being important for birds, as obtained from AVIREC:

1- Less than 5
2- Greater than or equal to 5, but less than 8
3- Greater than or equal to 8, but less than 10
4- Equal to 10

Entries in columns (m) to (x) are weightings on a scale of 1 to 10, indicating the suitability of applying certain constraints, advice or other management information. Column headings are as follows:

(m) Apply strict controls to powerboats on the surface water feature

(n) Apply strict controls to sailboards on the surface water feature

(o) No significant problems are forseen in the domains addressed

(p) Reduce the number of erven proposed, then recalculate the average size of erven and run SEWAGE to determine the change in likelihood of significant eutrophication occurring in the surface water feature, then run GENREC.

(q) Reduce the number of erven proposed, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised number of craft predicted to be using the area concerned, then run GENREC.

(r) Reduce the number of erven proposed, then recalculate the average size of erven and run SEWAGE to determine the change in likelihood of significant eutrophication occurring in the surface water feature, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised number of craft predicted to be using the area concerned, then run GENREC.

(s) Set the proposed resort further back from the boundary of the surface water feature, estimate the new setback distance and run SEWAGE to determine the change in likelihood of significant eutrophication occurring in the surface water feature, then run GENREC.

(t) Limit the numbers of craft concerned, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft using the water surface area then run GENREC.

(u) Prohibit powered craft from using the water surface area in question, then run PHYSREC to estimate the likelihood of exceeding the physical recreation carrying capacity for the other craft using the area concerned, then run GENREC.

(v) Investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the water surface area concerned.

(w) Investigate the emplacement or removal of barriers and corridors to direct specific recreational activities away from the area concerned.

(x) Consider turning down the development proposal.

Blank spaces appearing in the table indicate that the associated values are unimportant in the specific rule concerned.

3.4.5 The Design Prototype Consultation Procedure

The design prototype consultation procedure is described below (see fig. 2):

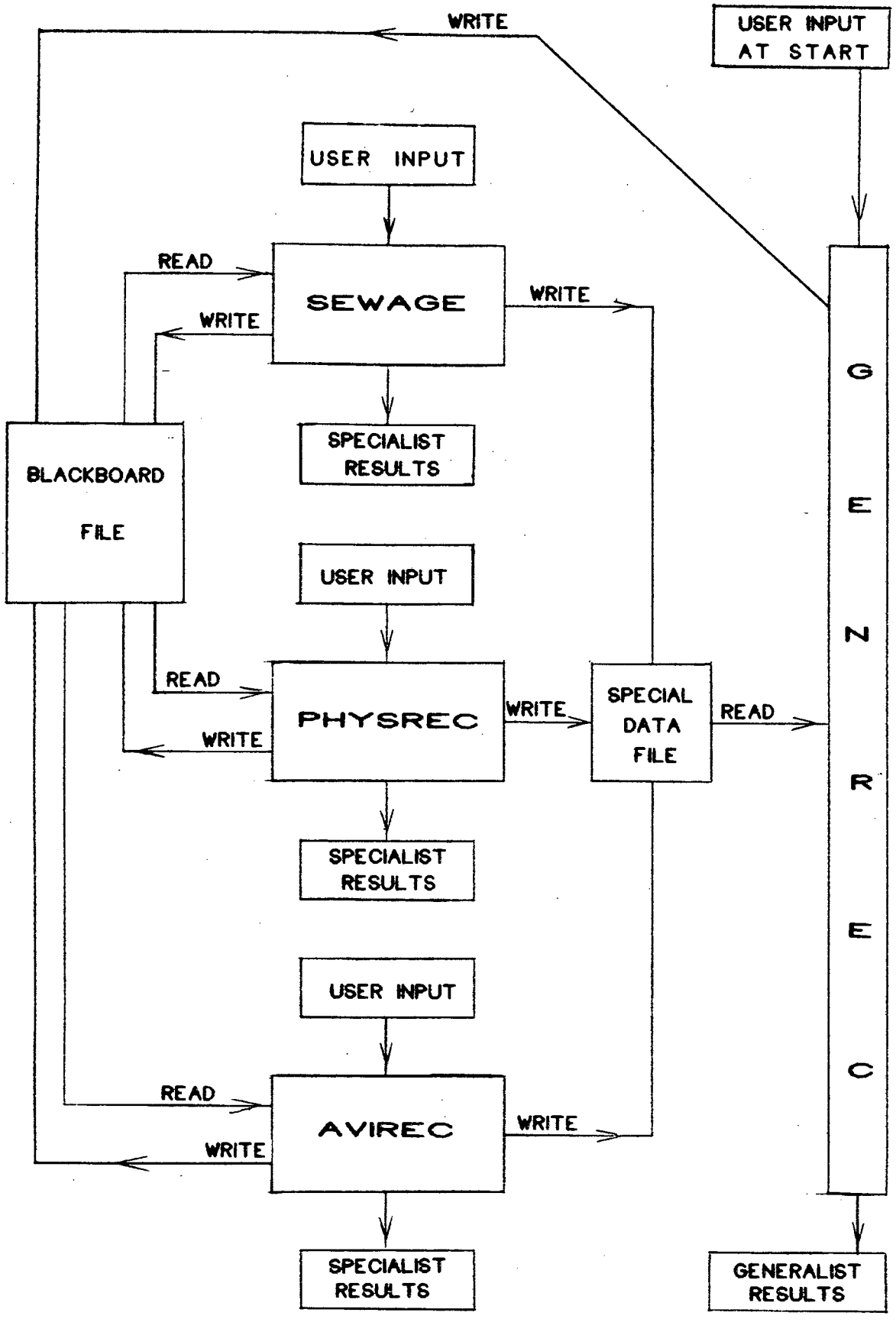

Figure 2: Components of the Designed Knowledge-Based Consultation Procedure

(1) At the start of the consultation procedure, information needed by more than one expert system is requested by the co-ordinating expert system, GENREC. This data is written immediately to a common data file (the "blackboard" file).

(2) The procedure itself incorporates a recursive "trial-and-error" process which entails the revision of certain assumptions (default values) during each trial consultation, in order to determine acceptable overall constraints to apply to a resort development proposal. During the first trial consultation the user assumes that the data in the development proposal, such as the number of erven proposed, is provisionally correct. These items of data form the assumptions referred to in the present study.

GENREC calls the specialist expert systems when they are needed, and each is run as it would be from the keyboard, with the following exceptions :

(a) Information shared by expert systems is read from the common data file (blackboard file) at the start of the run. The user is not re-asked for such information.

(b) At the end of the run the user is presented with the specialist system's results in the normal way. The user now has the option of storing all input information to a data storage file, for use at a later stage (there is an option in the development tool, EXSYS, which allows the user to do this). However, the results needed by GENREC are written into another data file without the user being aware of this. Control is then passed back to GENREC instead of to the user and GENREC reads the information in the data file before continuing the consultation.

(3) At the end of the first trial consultation, the results displayed by GENREC indicate which assumptions should be changed in order to approach an acceptable solution. These are presented to the user as weighted options such as:

(a) Reduce the number of proposed erven : 8/10

(b) Set the proposed resort further away from the boundary of the surface water feature : 7/10

(c) Prohibit powered craft from using the surface water feature.: 6/10

(d) Consider turning down the proposal : 4/10

The user may then decide which option to select and by how much to change the applicable assumption(s).

(4) A second trial consultation is then started by rerunning GENREC. During consequent trial consultations, when a specialist expert system is called up by GENREC, the user may elect to have the input data from a previous run recalled from the data storage file. Corrections to certain data (assumptions or default values) may then be made and the trial consultation continued. Only those specialist expert systems whose results are likely to be affected by the assumption(s) changed are called up by GENREC. At the end of a trial consultation, the user may compare results with those from the previous one, and so estimate to what extent changes need to be made to arrive at an acceptable solution. If further changes are minor, the user may terminate the consultation procedure. The corrected assumptions then become constraints applicable to the development proposal.

Weightings for these constraints need to be determined by the user and are seen to be partly dependent on the weightings of the results in the

final consultation, and the sensitivity of the results to changes in the constrained values.

(5) Constraints obtained at the end of a successful consultation procedure need not form a unique solution. If individual assumptions are changed by varying amounts, other sets of constraints may evolve. For example, acceptable sets of constraints for a specific resort development proposal might be:

a) Reduce the number of erven by 50% and set back the resort 100 metres from the boundary of the surface water feature.

b) Reduce the number of erven by 25%, set back the resort 150 metres from the boundary of the surface water feature and limit the number of craft using the surface water feature to current peak holiday population levels.

(c) Do not allow sewage disposal by septic tank, prohibit the use of powered craft in the surface water feature and provide alternative recreational amenities (such as a slipway to enable powered craft to gain access to the sea).

3.4.6 Special Problems

3.4.6.1 Adding Extra Rules to GENREC

In this section, the problem of adding extra rules to a functioning production system is addressed. The GENREC rule file originally consisted of only eighteen rules (rules 1 to 18 in Tables 3.4 and 3.5). Two more rules were then added to account for values of the product CF x **HIGH PROPORTION** which are greater than 2, and a further two rules to account for values greater than 3 (rules 19 to 22 in Table 3.5). At a later stage another ten rules were added to account for the

likelihood of the surface water feature being an important habitat for birds (rules 23 to 32 in Table 3.5).

Incorporating extra qualifiers directly into the rules in a functioning production system implies that more rules have to be constructed to account for the different values that each qualifier can take. This can result in an increase in the number of rules totally out of proportion to the increase in the accuracy of the solutions derived (Starfield and Bleloch, 1986). In order to investigate the ease with which a rule-based (production) system may be incrementally developed, and to prevent an inordinate increase in the number of rules resulting in a relatively small improvement in the solution, it was decided not to incorporate new qualifiers into the original rules.

Two approaches to adding extra knowledge to the GENREC rule file were taken. These are:

(1) Add extra rules and assign weights to goals addressed in these rules so that when an added rule and an original rule both try to evaluate a particular goal, the resultant value given to the goal is the one required. (These added rules are supposed to be applied together with other rules and not to stand alone.) An example follows:

> Suppose that an original rule assigns a weight of 5 to a goal when the value of a variable, C, exceeds 1. Later, it is desired to add a rule which causes the weight of the goal to change to 7 when the value of C exceeds 2. For values of C greater than 2, both of the above rules would then be applicable (see section 2.6) and, in order for a final weighting of 7 to be given to the goal, the added rule would need to have a value of 9 assigned to the goal within a rule conclusion. This problem arises because weights are averaged when two or more rules attempt to assign weights

to a particular goal (i.e.the.average of 5 and 9 is equal to 7). (see rules 19 and 20, Table 3.5)

(2) Add extra rules which evaluate additional choices not addressed by original rules (see choices **(m)** and **(n)** in rules 23 to 32, Table 3.5)

3.4.6.2 Sharing Common Input Data

Data required by more than one expert system should be stored to a data file so that it is accessible to those expert systems needing it. This will help to prevent the same question being asked of the user more than once during a consultation.

A data file may be created and written to by GENREC at the start of a consultation , using a rule which first asks the user for the required information. GENREC then uses a utility program within EXSYS (the expert system building tool) to create the file and write data into it. In order for an expert system to read this file, it is necessary that data in it be assigned to the correct variables and qualifiers in the expert system. EXSYS has an in-built facility which allows data to be passed to two or more expert systems when they are run in a predefined order:

> Suppose that two expert systems are to be run consecutively and that an item of data placed in the common data file (blackboard file) by GENREC is assigned to qualifier 3 for one expert system but is needed for qualifier 1 in the other.

The way to achieve this is to have the first expert system rewrite the data to the file at the end of its run in a form wich will cause the data to be assigned to qualifier 1 when the next expert system is consulted. However if the second expert system is run before the first or is run by itself, then the value for qualifier 1 will be incorrectly assigned to qualifier 3 in that expert system.

When expert systems are not run in a predetermined order, the only known way around this problem is to order the relevant qualifiers and variables within the expert systems so that they occupy the same places in each. The expert system building tool, EXSYS, does not facilitate the re-ordering of qualifiers and variables.

3.4.6.3 Passing Expert Information

In order for GENREC to obtain information from a specialist expert system, a calling function may be inserted into the text of a qualifier or variable within a precondition of a rule. When the rule is tested for applicability, instead of the user being asked for the information needed, the specialist expert system is run. The called system can then write the information required by GENREC into a special data file and the data can then be read by GENREC and placed in its working memory. If the data now in working memory validates the rule, the rule is fired. The calling function may be used to return multiple items of data to GENREC, even though some of the data may not be required to determine the applicability of the rule involved.

A problem encountered in the execution of EXSYS is that when one expert system calls up another, the called system does not write data to a file when directed to do so. This is the result of a "bug" in the development tool. However, when run from the keyboard, the called system writes the information as required. If the expert system needing the information is run from the keyboard, it reads the data written into the file when needed. If the file or records are not available, the user is asked for the required information instead.

A further problem encountered with EXSYS is that it does not allow the transfer of evaluated goals (choices in EXSYS) from one expert system to another unless there is only one item of data to be transferred. In order to overcome this hurdle, rules were used to convert goals (choices in EXSYS) to maths variables so that the numeric value of a specific variable reflects the weight given to the goal concerned.

The variables can then be transferred (see rule 80 in appendix VI).

3.4.6.4 The Position at Present

The problem of transferring data between expert systems using the EXSYS expert system development tool has not been resolved. The consultation procedure has therefore been amended for the present study, so that the user enters all the input data for each expert system during the first trial consultation and runs each expert system from the keyboard. Although more tedious, the amended procedure is similar to the consultation procedure aimed for and is discussed more fully in the following section.

3.4.7 The Amended Consultation Procedure

The prototype knowledge-based consultation system is designed to run without the user realizing that several expert systems are involved in the process. However, due to difficulties experienced with EXSYS in the transfer of data between participating expert systems, the user has to enter the required data and direct the consultation procedure from the keyboard in the following way:

(1) For the first trial consultation, the user runs SEWAGE, PHYSREC and AVIREC in any order from the keyboard as stand alone expert systems. At the end of each run, the option of having the input data stored to a special data file is selected. Recommended names for these files are SEWAGE.TMP, PHYSREC.TMP, and AVIREC.TMP respectively.

The user should note the following values :

(a) From SEWAGE, the value given to the maths variable: **EUTROPHICATION**

(b) From PHYSREC, the value given to the maths variable: **HI CONG FACTOR**

(c) From AVIREC, the values given to the two maths variables: NO POWERBOATS and HABITAT IMPORTANCE

(2) The user runs GENREC. When requested, the values of the maths variables noted from SEWAGE, PHYSREC and AVIREC, the management priorities for the area and the type of recreation considered must be supplied by the user. At the end of each trial consultation, GENREC displays one or more approaches, weighted according to their likelihood of being correct, which may be taken in order to come closer to an acceptable solution. A recommended approach may involve changing some assumption (input data) and running (i.e.consulting) one or more specialist systems before again consulting GENREC.

The user now decides which approach to take, then selects the option (offered by EXSYS) to store the input information into a data file, GENREC.TMP, before quitting GENREC.

(3) The second trial consultation is started by calling up the specialist expert system(s) concerned, retrieving information stored in the previous run and changing the necessary input data (assumptions) before running the specialist system(s) again (this may be done by using the "Change and rerun" option offered by EXSYS). The user should note the new values for the variables concerned. The user then runs GENREC again, enters the changed data and notes the changes in the results as well as in the recommendations (EXSYS displays the previous and current results side by side for comparison purposes). As a result of the comparisons, the user determines which approach to take, to what extent further changes need to be made to assumptions and proceeds to the next trial consultation.

If further changes are minor, the user may terminate the consultation procedure. The corrected

assumptions then become constraints applicable to the development proposal. Weightings for these constraints need to be determined by the user and are seen to be partly dependent on the weightings of the results in the final consultation and the sensitivity of the results to changes in the constrained values.

(4) The third and subsequent trial consultations are carried out in a similar manner to the procedure described in (3) above. The comments under (5) in section 3.4.6. are applicable.

3.4.8 Recommended Improvements

Recommendations for improvements to the knowledge-based consultation system are as follows:

(1) The prototype generalist expert system GENREC should be expanded to make decisions on the following information :

(a) From SEWAGE, the likely effects of septic tank effluent on groundwater and of surfacing effluent on dryland and wetland environments.

(b) From PHYSREC, the likely recreational congestion effects at current peak levels of use and also at future peak levels of use when all currently available erven are fully developed.

(c) From AVIREC, the recommended recreation management options of, *inter alia*: limiting craft numbers, prohibiting boardsailing or yachting in certain areas and applying speed limits to powered craft.

(d) From AVIREC, the need for further expert advice. For example, if fish specialist advice is needed, then GENREC could call the expert system concerned for advice.

(e) From AVIREC, the recommendations for official conservation status.

(f) From the user, *inter alia*: the presence of alternative bird refuges in the region; the presence of alternative resort development sites in the region; the proximity of other resorts and townships; the proximity of potential power and water supplies and sewage and waste disposal services.

(g) Add further goals which address constraints directly, for example: "Adopt an alternative form of sewage disposal."

(2) The data transfer problems encountered in using EXSYS need to be solved.

Recommendations for further development to GENREC are as follows:

(1) GENREC can be modified for educational and training purposes and for solving other multidisciplinary problems. This is facilitated by the modular nature of the specialist expert systems (Munn, 1979, p79).

(2) GENREC can be used to compare results when two sources of expertise come into conflict or when different schools of thought are involved. This may be achieved by calling up similar specialist expert systems which address the same domain of expertise.

Within a single specialist expert system, differing expert opinions may be incorporated in the rules by having two or more rules to each piece of knowledge, but with an extra precondition to each rule which reflects the expert's name or a school of thought.

3.4.9 Conclusion

GENREC is designed to coordinate the specialist prototype expert systems SEWAGE, PHYSREC and AVIREC so as to form a knowledge-based consultation system which aids decision-makers involved in the assessment of proposed resort developments adjacent to surface water features in the coastal zone. The exercise of designing and constructing GENREC demonstrates that it is feasible to use one expert system to integrate others, representing diverse bodies of knowledge and reasoning methods, into a problem-solving system whose objectives may be different from those of the participating expert systems.

A serious limitation encountered in the current task is that the automatic transfer of data between co-operating expert systems is not facilitated by the current versions of EXSYS.

CHAPTER 4

SUMMARY AND CONCLUSIONS

4.1 Introduction

This study aimed to determine the feasibility of using expert systems as a decision support system for decision-makers who are undertaking environmental assessments of coastal resort development proposals. The investigation was limited to production systems able to be run on a personal computer with two disc drives and 640K bytes of random access memory.

4.2 The Study

The study addressed four main problems. First it considered the features which need to be displayed by a production system in order for it to be suitable to address problems often encountered in natural resource management. It was shown that a suitable production system should be able to, *inter alia*:

(a) perform forward and then backward reasoning on the rules.

(b) test all the rules in the order that they appear in the rule file.

(c) work with rules which have both multiple preconditions and multiple conclusions.

(d) work with partial or uncertain knowledge and to have available different methods for combining or selecting weighting factors when two or more rules work together either serially or in parallel.

(e) call up an expert system (or other program) and to pass multiple items of data to it in suitable format, either via a data file or by other means.

(f) read multiple items of data from a file and to assign them to relevant variables and qualifiers before and during a run.

(g) work with maths variables and formulae.

(h) allow evaluated goals to be used in the preconditions of rules.

The study next considered problem-solving characteristics and methods suitable for determining likely solutions to problems of a multi-disciplinary nature, in natural resource management. The following were found to be important:

(a) The application of the least-commitment principle and the related concept of constraint satisfaction.

(b) A recursive "trial-and-error" problem-solving procedure in which corrections to certain assumptions (default values) are applied, the effect of these changes on the values of one or more goals is noted, and on the basis of these changes, further corrections are then made to the assumptions so as to change goal values to more acceptable ones. The revised assumptions may then become suitable constraints to apply to development proposals and to recreation management.

A knowledge-based consultation system, consisting of specialist, stand-alone production systems co-ordinated by a production system of a more general nature, was then described. The specialist production systems were designed to address specific sub-domains of a problem area. The other was designed to co-ordinate them and to use their results to help determine suitable approaches to finding acceptable development constraints and management options to apply in a natural resource management problem.

Finally, a prototype knowledge-based consultation system, consisting of four separate prototype production systems, was developed. The first three were specialist production systems, each addressing a domain of specialist expertise. The fourth addresses a domain of higher level, or "multi-disciplinary" expertise.

The first system developed, SEWAGE, estimates the likelihood of eutrophication occurring in a surface water feature as the result of septic tank effluent disposal from an adjacent, proposed resort development.

The second, PHYSREC, estimates the likelihood of exceeding the recreational carrying capacity for craft on a body of water at current and possible future peak levels of use.

The third, AVIREC, determines recreational management options for craft using a surface water feature which is also used by birds for foraging, roosting and breeding. it also estimates the likelihood of the feature being an important habitat for birds.

The fourth prototype production system, GENREC, was designed to co-ordinate the three specialist systems to form a prototype knowledge-based consultation system. It was designed to aid the decision-maker in determining constraints that may be suitably applied to a resort development proposal in order to reduce the likelihood of significant impacts. A third function was to allow it to take into take into account management options and management priorities for the area.

4.3 Final Conclusion

Results of the study indicate that an expert systems approach to multi-disciplinary problems in coastal-zone management is feasible. Stand-alone specialist expert systems can be developed for particular sub-systems of natural resource management problems, such systems have been developed before and three were developed for this study.

This study demonstrates further that a co-ordinated group of specialist expert systems, under the control of another expert system, developed to aid decision-makers in coastal zone management and development planning is feasible. The aim of the study, that is, to determine the feasibility of using expert systems as a decision-support system for decision-makers undertaking preliminary environmental assessments of coastal resort development proposals, has thus been achieved.

REFERENCES

Aikins, J.S. 1983: Prototypical Knowledge for Expert Systems, *Artificial Intelligence*, Vol. 20, 163-210.

Alty, J.L. & Coombs, M.J. 1984: *Expert Systems - Concepts and Examples*, Manchester: NCC Publications.

Barr, A. & Feigenbaum, E.A. (eds.) 1982: *The Handbook of Artificial Intelligence*, Vol. 2, Los Altos, Calif: Kauffmann.

Bramer, M.A. 1982: A survey and Critical Review of Expert Systems Research in *Introductory Readings in Expert Systems*, D. Michie (ed.), London: Gordon & Breach.

Brachman, R.J. 1977: What's in a Concept: Structural Foundations for Semantic Networks, *Int. J. of Man-Machine Studies*, Vol. 9, 127-152.

Brooke, R.K. 1984: *South African Red Data Book-Birds*, S. Afr. Nat. Sci. Programmes Report No. 97, Pretoria: C.S.I.R.

Clark, J.R. 1977: *Coastal Ecosystem Management*, New York: John Wiley & Sons

Davies, B.R. & Day, J.A. 1986: *The Biology and Conservation of South Africa's Vanishing Waters*, University of Cape Town: The Centre for Extra-Mural Studies.

Davis, J.R. & Nanninga, P.M. 1985: GEOMYCIN: Towards a Geographic Expert System for Resource Management. *J. Env. Management*, Vol. 20, no. 4, 377-390.

De Roos, G.T. 1981: *The Impact of Tourism upon some Breeding Wader Species on the Isle of Vlieland in the Netherlands Wadden Sea*, Wageningen: H. Veenman & Zonen, B.V.

Erman, L.D., Hayes-Roth, F., Lesser, V. & Reddy, D. 1980: The HEARSAY-II Speech Understanding System: Integrating Knowledge to Resolve Uncertainty, *Computing Surveys*, Vol. 12, No. 2, 213-253.

Fiddes, D.A. 1985: Expert Systems in Water Supply and Sanitation in *Developing World Water*, J. Pickford & B. Leedham (eds.), London: Grosvenor Press International.

Fuggle, R.F., & Rabie, M.A. (eds) 1983: *Environmental Concerns in South Africa*, Cape Town: Juta & Co.

Gaschnig, J. 1982: Prospector: An Expert System for Mineral Exploration in *Introductory Readings in Expert Systems*, D. Michie (ed.), London: Gordon & Breach.

Grey, D.C. 1986: Information Profile: Expert Systems, (Unpublished Report), Saasveld Forestry Research Centre, George.

Hart, R.C. & Allanson, B.R. (eds.) 1984: *Limnological Criteria for Management of Water Quality in the Southern Hemisphere*, S. Afr. Nat. Sci. Programmes Report No. 93, Pretoria: C.S.I.R.

Hayes-Roth, F. 1985: Rule-Based Systems, *Communications of the Association for Computing Machinery*, Vol. 28, No. 9, 921-932.

Hayes-Roth, F., Waterman, D.A. & Lenat, D.B. (eds.) 1983: *Building Expert Systems*, Reading, Mass: Addison-Wesley.

Huntingdon, D. 1987: Expert System Development Package Manual, Albuquerque, N.M.: Exsys Inc.

Lehmer, P.E. & Barth, S.W. 1985: Expert Systems on Micro-Computers, *Expert Systems*, Vol. 2, No. 4, 198-208.

Miller, A.M., Pople, H.E. & Myers, J.D. 1982: INTERNIST-I: An Experienced Computer-Based Diagnostic Consultant for General Internal Medicine, *New England J. of Medicine*, No. 307, 468-476.

Mooneyham, D.W. 1983: The Potential of Expert Systems for Remote Sensing, 17th Int. Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan, 51-64.

Munn, R.E. (ed.) 1979: *Environmental Impact Assessment*, SCOPE 5, N.Y.: John Wiley & Sons.

Newell, A. & Simon, H.A. 1972: *Human Problem Solving*, N.J.: Prentice-Hall.

O'Hare, G.M. & Bell, D.A. 1985: The Co-existence Approach to Knowledge Representation, *Expert Systems*, Vol. 2, No. 4, 230-234.

O'Keefe, J.H., Danielewitz, D.B. & Bradshaw, J.A. 1986: The River Conservation System: A Users Manual, Ecosystem Programmes Occasional Report Series No. 9, Pretoria: C.S.I.R.

Pau, L.F. 1986: Survey of Expert Systems for Fault Detection, Test Generation and Maintenance, *Expert Systems*, Vol. 3, No. 2, 100-111.

Pollitt, A.S. 1986: Reducing Complexity by Rejecting the Consultation Model as a Basis for the Design of Expert Systems, *Expert Systems*, Vol. 3, No. 4, 234-238.

Quinlan, J.R. 1982: Semi-Autonomous Aquisition of Pattern-Based Knowledge in *Introductory Readings in Expert Systems*, D. Michie (ed.), London: Gordon & Breach.

Rich, E. 1983: *Artificial Intelligence*, New York: McGraw-Hill.

Richey, J.S., Mar, B.W. and Horner, R.R. 1985: The Delphi Technique in Environmental Assessment, *J. of Environmental Management*, Vol. 21, 135-146.

Rowlands, B.W. 1984: The Effects of Recreational Activities on Aquatic Avifauna, M.Sc. Thesis (unpublished), School of Environmental Studies, University of Cape Town.

Ryan, P.G., Cooper, J., Hockey, P.A.R. & Berruti, A. 1986: Waders (Charadrii) and other Water Birds on the Coast and Adjacent Wetlands of Natal, *Lammergeyer*, Vol. 36, 1-33.

Sagalowicz, D. 1984: Development of an Expert System, *Expert Systems*, Vol. 1, No. 2, 137-142.

Sowman, M.R. & Fuggle, R.F. 1987: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa, *J. of Shoreline Management*, Vol. 3, 53-75.

Shortliffe, E.H. 1976: *Computer-Based Medical Consultation: MYCIN*, N.Y.: Elsevier.

Starfield, A.M. & Bleloch, A.L. 1983: Expert Systems: An Approach to Problems in Ecological Management that are Difficult to Quantify, *J. of Environmental Management*, Vol. 16, 261-268.

Starfield, A.M. & Bleloch, A.L. 1986: *Building Models for Conservation and Wildlife Management*, N.Y.: MacMillan.

Stefik, M.J. 1980: Planning with Constraints, Ph.D. dissertation, Heuristic Programming Project, Standford University, C.A.

Van Melle, W. 1979: A Domain Independent Production-Rule System for Consultation Programs, International Joint Conference on Artificial Intelligence 6, Tokyo, 923-925.

Wall, G. & Wright, C. 1977: The Environmental Impact of Outdoor Recreation, Department of Geography Publication Series No. 11, Waterloo, Ontario: University of Waterloo.

Waterman, D.A. 1977: An Introduction to Production Systems, *A.I.S.B. European Newsletter*, No. 25, 7-10.

Weiss, S.M. & Kulikowski, C.A. 1984: *A Practical Guide to Building Expert Systems*, N.J.: Rowman & Allanheld.

Winston, P.H. 1977: *Artificial Intelligence*, Reading, Mass: Addison-Wesley.

APPENDIX I

EXSYS: THE EXPERT SYSTEM BUILDING TOOL

1. The Development Tool

The expert system building tool (or "shell") selected for present prototype modelling purposes is EXSYS, a tool suitable for developing expert systems on micro-computers (D. Huntingdon, 1987).

2. EXSYS

2.1 Reasons for choosing EXSYS:

EXSYS was chosen for the following reasons:

(1) It displays many of the features suitable for solving the types of problem addressed in this study.

(2) It is freely available.

(3) It is suitable for use on a personal computer.

(4) It is being continually updated, and rule files created with previous versions are easily converted to run on later editions.

(5) It has explanation facilities provided for rules and to help the user in running the software.

(6) It has a user-friendly rule editing program which makes encoding, editing and "de-bugging" easy to do.

2.2 Features of EXSYS

Features of EXSYS which make it suitable for addressing the prototype problem characteristics are as follows:

(1) It is a production rule system and therefore has the benefits associated with these systems (See section 2.3).

(2) It can do forward or backward reasoning or combinations of the two.

(3) It can address multiple-valued goals (choices in EXSYS) and several goals at the same time.

(4) It accomodates the use of weighting factors in the rules.

(5) It allows evaluated goals to be used in the preconditions of rules (see subsection 3.1.4 of chapter 3)

(6) It is able to communicate with and run other programs:

   (a) It can write data to a file on disk and call up other programs to read and work with it. (However there are limitations to the situations in which it does this.)

   (b) It can read suitably formatted data from a disk file.

(7) It can undertake functional computations which are embedded in the rules. This allows an intermixing of functional algorithms with heuristic knowledge (similar to the way an expert may work with a scientific semi-programmable calculator).

(8) It allows the user to test and analyse the effect that a change in user input has on a solution. In the present study, this feature is used to enable a prior assumption to be retracted once further information gained has invalidated it.

(9) It has a user-friendly editing program which facilitates the encoding of rules and it also checks for redundant rules.

2.3 Evaluation of Weights in EXSYS

Exsys can handle both facts and beliefs, but is limited in the way that weighting of beliefs may be computed. When several rules attempt to apply weights to a goal (choice in EXSYS), the final value given to that goal may be calculated in one of the following ways:

(1) Weights may be applied as if they are either dependent or independent probabilities.

(2) The average of the weights is taken, except when one of the values is 0/10 or 10/10, in which case either the minimum (0/10) or else the maximum (10/10) weighting is taken as the final one.

Exsys has fallible weighting evaluators, and it is therefore possible to discard a good solution as a result of having weak evidence (see chapter 2, sections 2.6 and 2.7).

2.4 Rules in EXSYS

A precondition of a rule in EXSYS is usually a statement such as "The bird is roosting". A qualifier is that part of a statement which does not change, for example, "The bird is". A value is that part which changes, for example: "roosting", "breeding", "feeding", "moulting", and so on. When a question is asked of the user, it appears as "THE BIRD IS..." and the expected answer is one or more values from a pre-specified list of possible values in the form of a menu:-

```
1.   BREEDING
2.   ROOSTING
3.   FEEDING
4.     .......
```

The user selects a number as the answer. This data is then added to the data in the working memory.

A conclusion in a rule may be a similar statement (i.e. a statement of fact) or a statement with a weighting attached to it (a statement of belief). A statement of belief in EXSYS is known as a choice.

A rule in EXSYS can have more than one preconditon and more than one conclusion. It may take the form shown in the following example:

```
IF
     Qualifier  1  Value  2
     Qualifier  2  Value  4
     Qualifier  5  Value  1

THEN
     Qualifier  7  Value  3
     Choice  3  p  =  4/10
     Choice  10  p  =  7/10

NOTE:     ..............................................

REFERENCE:     ..........................................
```

In the IF part of the rule, the qualifiers are questions asked and the numbered values are the answers selected from the menu of possible answers to each question asked. In the THEN part, the qualifier is given the value specified and the numbered choices are given the weightings specified. The note explains the reason for the rule and the reference refers to the source of expertise from where the knowledge was derived.

3. Conclusion

EXSYS does not have a sophisticated probabilistic reasoning mechanism, but it is able to represent a fairly wide range of problem-solving expertise within the limited resources of a personal computer.

APPENDIX II

KNOWLEDGE REPRESENTATION

1. Knowledge Types

Production systems typically use a single set of rules to represent differing types of expert knowledge. This knowledge may be categorized as factual, heuristic, contextual or control knowledge

Factual and heuristic knowledge represent descriptive and problem solving knowledge (which are described in chapter 2 of this thesis). Factual knowledge is certain and unconditonally valid. Heuristic knowledge may be uncertain, judgemental, and only partially valid (Sagalowicz, 1984).

Both factual and heuristic knowledge may be considered as consisting of deep and shallow knowledge. Deep knowledge contains information about underlying causes and effects and uses the basic principles of the problem domain addressed (Alty and Coombs, 1984). Shallow knowledge uses "rules-of-thumb" and empirical relationships which help to "skim the surface" and to simplify complex relationships (Sagalowicz, 1984). Multidisciplinary problems of the kind addressed in this thesis usually require only shallow knowledge for their solution.

Contextual and control knowledge represent metalevel (i.e.knowledge about knowledge) or abstract knowledge (Alty and Coombs, 1984; Hayes-Roth et al., 1983). Contextual knowledge defines in which contexts or situations other knowledge holds true (Bramer, 1982; Alty and Coombs, 1984). Control knowledge is generally used to direct inference and input/output processes.

An example to explain contextual knowledge follows:

Given the set of production rules:

IF A AND B AND C THEN X
IF A AND B AND D THEN Y
IF A AND B AND E THEN Z

Assume precondition A is true. In order to determine the applicability of the above rules, preconditions A and B would be tested for validity three times each. However if these rules are changed to the following form, A and B would only need to be verified once:

IF A AND B THEN:

IF C THEN X
IF D THEN Y
IF E THEN Z

In this form, A and B is contextual knowledge, which is knowledge that needs to be verified before the modified rules may be tested for validity. (This is another way of saying that statements must be viewed in the correct context before their validity can be ascertained). This form of knowledge representation can mean significant savings in computer processing time (Alty & Coombs, 1984; Hayes-Roth et. al., 1983; O'Hare and Bell, 1985).

In a production system, large rule files can be subdivided into smaller files, each headed by contextual knowledge. Production systems working with such rule files are known as structured production systems (Pau, 1986). These systems should be particularly suitable for working with spatially and temporally varying information.

2. The Aquisition and Codification of Knowledge

The procedure of extracting knowledege and know-how from a source of expertise, then re-organising it so as to be in a form compatible for coding into a suitable program is called "knowledge engineering" (Barr and Feigenbaum, 1982; Pau, 1986). There are many references in the literature to

knowledge engineering being a time-consuming and difficult problem (Barr and Feigenbaum, 1982; Quinlan, 1982; Hayes-Roth et. al., 1983; Alty and Coombs, 1984). It is seen as being the major bottleneck in the production of expert systems (Barr and Feigenbaum, 1982)

APPENDIX III

DESCRIPTION OF A TYPICAL RESORT DEVELOPMENT PROPOSAL ASSESSMENT TASK

When a resort-development proposal application is received for comment and approval at the Cape Town office of the Department of Environment Affairs (and at the Cape Department of Nature and Environmental Conservation), information on the geographic area (in a local and regional context) is gathered. This includes general and specialized maps and atlases, correspondence on local environmental issues, photographs, and so on.

Preliminary consultations with experts are held. These experts include those who have knowledge of the local area and its people, relevant administrative, political and legal specialists and interdisciplinary experts. At this stage, overall priorities and objectives are revealed and likely problem areas outlined.

Experts with in-depth knowledge in the potential problem domains are sought, the key issues are crystallized, further sources of expertise identified, and site visits conducted. The latter is carried out with the relevant experts where feasible. The investigator, who is usually a multi-disciplinary expert, is alerted to identify relevant field indicators and to take certain measurements and tests and to gather other information required.

If there is now sufficient information to define one or more acceptable solutions (each of which may consist of development constraints, recommended management options and advice), these are presented to the decision-maker(s) for selection and/or approval. However, it may be the case that there needs to be more confirmatory evidence collected for an acceptable solution to be derived. In the latter case, further experts may need to be consulted and other evidence collected so as to confirm or deny tentative conclusions.

The final solution is usually chosen in light of overall mangement and planning priorities for the area.

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University of Cape Town

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APPENDIX IV

SEWAGE: RULES, QUALIFIERS, , CHOICES AND VARIABLES

Subject:

Septic tank effluent dispoasal

Starting text:
Septic tank and pit sewage disposal can have a significant environmental impact on surface water features, on health, indigenous vegetation, groundwater, etc..
.....
RULES:

RULE NUMBER: 1

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or silty or loamy
and Subsoil is clayey
and average erf size is less than 500 sq.m.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours, disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=6/10

NOTE:
Clay soils are nearly impervious to septic tank effluent.

RULE NUMBER: 2

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is clayey
and Subsoil is NOT impermeable bedrock or unknown,but considered to be impermeable.
and average erf size is less than 500 sq.m.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease

vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=9/10

and Consider alternative means of sewage disposal. - Probability=9/10

NOTE:
Clay soils are nearly impervious to septic tank effluent.

RULE NUMBER: 3

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is clayey
and Subsoil is NOT impermeable bedrock or unknown,but considered to be impermeable.
and average erf size is between 500 and 1000 sq.m.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=7/10

and Consider alternative means of sewage disposal. - Probability=7/10

NOTE:
Clay soils are nearly impervious to septic tank effluent.

RULE NUMBER: 4

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is clayey
and Subsoil is NOT impermeable bedrock or unknown, but considered to be impermeable
and average erf size is more than 1000 sq.m.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=4/10

and Some impact from the proposed method of sewage disposal is likely. However,if the mitigating measures are investigated and applied according to expert specifications, results should be cost-effective. - Probability=7/10

and investigate possibility of creating a built-up soakage field that is planted to suitable vegetation which is efficient at taking up phosphates, nitrates and water from the soil.

NOTE:
Clay soils are nearly impervious to septic tank effluent.

RULE NUMBER: 5

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is clayey
and Subsoil is impermeable bedrock or unknown, but considered to be impermeable.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=9/10

and Consider alternative means of sewage disposal. - Probability=10/10

RULE NUMBER: 6

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is impermeable bedrock
and average erf size is less than 500 sq.m.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=9/10

and Consider alternative means of sewage disposal. - Probability=9/10

RULE NUMBER: 7

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy

and Subsoil is permeable bedrock
and average erf size is between 500 and 1000 sq.m.

THEN:
A major impact on groundwater quality is likely. Probprobability=6/10

and Consider alternative means of sewage disposal. - Probability=6/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=6/10

NOTE:
insufficiently treated effluent is likely to enter groundwater aquifers.

RULE NUMBER: 8

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or silty or loamy
and Subsoil is impermeable bedrock
and average erf size is between 500 and 1000 sq.m.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=5/10

RULE NUMBER: 9

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or silty or loamy
and Subsoil is impermeable bedrock.
and average erf size is more than 1000 sq.m.

THEN:
Some impact from the proposed method of sewage disposal is likely. However,if the mitigating measures are investigated and applied according to expert specifications, results should be cost-effective. - Probability=5/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=5/10

and investigate possibility of creating a built-up soakage field that is planted to suitable vegetation which is efficient at taking up phosphates, nitrates and water from the soil.

and Consider alternative means of sewage disposal. - Probability=5/10

RULE NUMBER: 10

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is permeable bedrock
and average erf size is less than 500 sq.m.

THEN:
A major impact on groundwater quality is likely - Probability=9/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=6/10

and Consider alternative means of sewage disposal. - Probability=10/10

RULE NUMBER: 11

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is impermeable bedrock or permeable bedrock

THEN:
Consider alternative means of sewage disposal. - Probability=10/10

RULE NUMBER: 12

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is permeable bedrock
and average erf size is more than 1000 sq.m.

THEN:
A major impact on groundwater quality is likely. - Probability=4/10

and Septic tank effluent could come to the sur e, resulting in the presence of scum,bad odours,di vectors,etc.,in certain locations such as in dips d hollows,seepage areas ,etc. - Probability=2/10

and Consider alternative means of sewage disposal. - Probability=4/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=5/10

RULE NUMBER: 13

IF:
sewage disposal is by septic tank or by soakage pit
and the highest seasonal level of groundwater table is above ground

THEN:
A major impact on groundwater quality is likely. - Probability=10/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=10/10

and Consider alternative means of sewage disposal. - Probability=10/10

RULE NUMBER: 14

IF:
sewage disposal is by septic tank or by soakage pit
and the highest seasonal level of groundwater table is within 0,3m.of surface

THEN:
A major impact on groundwater quality is lik y. - Probability=10/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=9/10

and Consider alternative means of sewage disposal. - Probability=10/10

RULE NUMBER: 15

IF:
sewage disposal is by septic tank or by soakage pit
and average erf size is less than 500 sq.m.
and the highest seasonal level of groundwater table is between 0,3m. and 2,0m. of surface

THEN:
A major impact on groundwater quality is likely. - Probability=8/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=8/10

and Consider alternative means of sewage disposal. - Probability=9/10

and Obtain expert advice on soil suitability and the possible negative effects resulting from a high groundwater level. - Probability=10/10

RULE NUMBER: 16

IF:
sewage disposal is by septic tank or by soakage pit
and average erf size is between 500 and 1000 sq.m.
and the highest seasonal level of groundwater table is between 0,3m. and 2,0m. of surface

THEN:
A major impact on groundwater quality is likely. - Probability=7/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=7/10

and Consider alternative means of sewage disposal. - Probability=8/10

and Obtain expert advice on soil suitability and the possible negative effects resulting from a high groundwater level. - Probability=10/10

RULE NUMBER: 17

IF:
sewage disposal is by septic tank or by soakage pit
and average erf size is more than 1000 sq.m.
and the highest seasonal level of groundwater table is between 0,3m. and 2,0m. of surface

THEN:
A major impact on groundwater quality is likely. - Probability=5/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=6/10

and Consider alternative means of sewage disposal. - Probability=6/10

and Obtain expert advice on soil suitability and the possible negative effects resulting from a high groundwater level. - Probability=10/10

RULE NUMBER: 18

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is sandy or stony or silty or permeable bedrock.
and average erf size is less than 500 sq.m.
and the highest seasonal level of groundwater table is between 2m. and 3m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=8/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=3/10

and Consider alternative means of sewage disposal. - Probability=7/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=10/10

RULE NUMBER: 19

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is sandy or stony or silty or permeable bedrock.
and average erf size is between 500 and 1000 sq.m.
and the highest seasonal level of groundwater table is between 2m. and 3m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=7/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=2/10

and Consider alternative means of sewage disposal. - Probability=6/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=10/10

RULE NUMBER: 20

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is sandy or stony or silty or permeable bedrock.
and average erf size is more than 1000 sq.m.
and the highest seasonal level of groundwater table is between 2m. and 3m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=6/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=2/10

and Consider alternative means of sewage disposal. - Probability=5/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=9/10

RULE NUMBER: 21

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is clayey or loamy/humic
and average erf size is less than 500 sq.m.
and the highest seasonal level of groundwater table is between 2m. and 3m. of surface.

THEN:
Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=5/10

and A major impact on groundwater quality is likely. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=5/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=8/10

RULE NUMBER: 22

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is clayey or loamy/humic
and average erf size is between 500 and 1000 sq.m.
and the highest seasonal level of groundwater table is between 2m. and 3m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=4/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=3/10

and Consider alternative means of sewage disposal. - Probability=3/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=6/10

RULE NUMBER: 23

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is clayey or loamy/humic
and average erf size is more than 1000 sq.m.
and the highest seasonal level of groundwater table is between 2m. and 3m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=2/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=5/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=5/10

RULE NUMBER: 24

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is sandy or stony or silty or permeable bedrock.
and average erf size is less than 500 sq.m.
and the highest seasonal level of groundwater table is between 3m. and 4m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=5/10

and Septic tank effluent could come to the surface, resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc. - Probability=2/10

and Consider alternative means of sewage disposal. - Probability=5/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=8/10

RULE NUMBER: 25

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loam
and Subsoil is sandy or stony or silty
and average erf size is between 500 and 1000 sq.m.
and the highest seasonal level of groundwater table is between 3m. and 4m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=4/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=6/10

RULE NUMBER: 26

IF:
sewage disposal is by septic tank or by soakage pit
and Surface soil is sandy or stony or silty or loamy
and Subsoil is sandy or stony or silty
and average erf size is more than 1000 sq.m.
and the highest seasonal level of groundwater table is between 3m. and 4m. of surface.

THEN:
A major impact on groundwater quality is likely. - Probability=3/10

and Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent. - Probability=4/10

RULE NUMBER: 27

IF:
sewage disposal is by septic tank or by soakage pit
and A major impact on groundwater quality is likely. Probability - > 5/10
and the type of water feature is a coastal lake
and shortest distance to the water feature bounda
NOT more than 300m.

THEN:
Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and\around the surface water feature. - Probability=8/10

and Consider alternative means of sewage disposal. - Probability=9/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=10/10

NOTE:
Coastal lakes usually have a high conservation status.The likelihood of pollution needs to be minimized.

RULE NUMBER: 28

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is a vlei or stagnant portion of an estuary or an estuary, open to the sea occasionally
and shortest distance to the water feature boundary is NOT between 100 & 300m. or more than 300m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=6/10

and Consider alternative means of sewage disposal. - Probability=10/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=10/10

RULE NUMBER: 29

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is an estuary,open to the sea for more than six months per year or an estuary,open to the sea seasonally only
and shortest distance to the water feature boundary is less than 10m. or between 10 & 30m. or between 30 & 50m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=6/10

and Consider alternative means of sewage disposal. - Probability=10/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=10/10

RULE NUMBER: 30

IF:

sewage disposal is by septic tank or by soakage it

and the type of water feature is a seasonal stream or river or a perennial stream or river or an estuary,open to the sea all year or the seashore or other
and shortest distance to the water feature boundary is less than 10m. orbetween 10 & 30m.
and A major impact on groundwater quality is likely. > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=6/10

and Consider alternative means of sewage disposal. - Probability=10/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=5/10

RULE NUMBER: 31

IF:

sewage disposal is by septic tank or by soakage pit

and the type of water feature is a seasonal stream or river or a perennial stream or river or an

estuary,open to the sea all year or the seashore or other

and shortest distance to the water feature boundary is between 30 & 50m. or between 50 & 100m.

and A major impact on groundwater quality is likely. > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=8/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=5/10

RULE NUMBER: 32

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is a seasonal stream or river or a perennial stream or river or an estuary,open to the sea all year or the seashore or other
and shortest distance to the water feature boundary is between 100 & 300m.
and A major impact on groundwater quality is likely. > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=4/10

and Consider alternative means of sewage disposal. - Probability=6/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=5/10

RULE NUMBER: 33

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is a seasonal stream or river or a perennial stream or river or an estuary,open to the sea all year or the seashore or other
and shortest distance to the water feature boundary is more than 300m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=3/10

and Consider alternative means of sewage disposal. - Probability=4/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=4/10

RULE NUMBER: 34

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is an estuary,open to the sea for more than six months per year or an estuary, open to the sea seasonally only
and shortest distance to the water feature boundary is between 50 & 100m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=9/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. -Probability=9/10

RULE NUMBER: 35

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is an estuary, open to the sea for more than six months per year or an estuary,open to the sea seasonally only
and shortest distance to the water feature boundary is between 100 & 300m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=9/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=9/10

RULE NUMBER: 36

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is an estuary,open to the sea for more than six months per year or an estuary,open to the sea seasonally only
and shortest distance to the water feature boundary is more than 300m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=4/10

and Consider alternative means of sewage disposal. - Probability=7/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=8/10

RULE NUMBER: 37

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is a vlei or stagnant portion of an estuary or an estuary, open to the sea occasionally
and shortest distance to the water feature boundary is between 100 & 300m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=9/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=9/10

RULE NUMBER: 38

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is a vlei or stagnant portion of an estuary or an estuary, open to the sea occasionally
and shortest distance to the water feature boundary is more than 300m.
and A major impact on groundwater quality is likely. Probability - > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely tooccur in and around the surface water feature. - Probability=4/10

and Consider alternative means of sewage disposal. - Probability=7/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=8/10

RULE NUMBER: 39

IF:

sewage disposal is by septic tank or by soakage pit
and the type of water feature is a coastal lake
and shortest distance to the water feature boundary is more than 300m.
and A major impact on groundwater quality is likely. Probability = > 5/10

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=5/10

and Consider alternative means of sewage disposal. - Probability=9/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=9/10

RULE NUMBER: 40

IF:

sewage disposal is by septic tank or by soakage pit
and the highest seasonal level of groundwater table is unknown
and the type of water feature is NOT a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea occasionally
and shortest distance to the water feature boundary is less than 10m. or between 10 & 30m.

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. - Probability=4/10

and Consider alternative means of sewage disposal. - Probability=6/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=9/10

RULE NUMBER: 41

IF:

sewage disposal is by septic tank or by soakage pit
and the highest seasonal level of groundwater table is unknown
and the type of water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea occasionally
and shortest distance to the water feature boundary is less than 10m. or between 10 & 30m. or between 30 & 50m.

THEN:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely tooccur in and around the surface water feature. - Probability=4/10

and Consider alternative means of sewage disposal. - Probability=6/10

and Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question. - Probability=9/10

RULE NUMBER: 42

IF:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability = < 5/10
and Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability = > 0/10

THEN:

[SEWAGE POLLUTION] IS GIVEN THE VALUE 3

and [EUTROPHICATION] IS GIVEN THE VALUE 3

RULE NUMBER: 43

IF:

Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability = = 5/10

THEN:
[SEWAGE POLLUTION] IS GIVEN THE VALUE 5

and [EUTROPHICATION] IS GIVEN THE VALUE 5

RULE NUMBER: 44

IF:
Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability - = 6/10

THEN:
[SEWAGE POLLUTION] IS GIVEN THE VALUE 6

and [EUTROPHICATION] IS GIVEN THE VALUE 6

RULE NUMBER: 45

IF:
Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability - = 7/10

THEN:
[SEWAGE POLLUTION] IS GIVEN THE VALUE 7

and [EUTROPHICATION] IS GIVEN THE VALUE 7

RULE NUMBER: 46

IF:
Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability - = 8/10

THEN:
[SEWAGE POLLUTION] IS GIVEN THE VALUE 8

and [EUTROPHICATION] IS GIVEN THE VALUE 8

RULE NUMBER: 47

IF:
Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability - = 9/10

THEN:
[SEWAGE POLLUTION] IS GIVEN THE VALUE 9

and [EUTROPHICATION] IS GIVEN THE VALUE 9

RULE NUMBER: 48

IF:
Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature. Probability - = 10/10

THEN:
[SEWAGE POLLUTION] IS GIVEN THE VALUE 10

and [EUTROPHICATION] IS GIVEN THE VALUE 10

QUALIFIERS:

1 sewage disposal is

by septic tank
by soakage pit
by self-contained "mini" sewage treatment plant.
by storage container
by municipal or local authority sewage works.
not applicable to this run
by method unknown.

2 Subsoil is

clayey
sandy
stony
silty
loamy/humic
impermeable bedrock.
permeable bedrock.
unknown,but considered to be impermeable.
unknown,but considered to be permeable.

3 Surface soil is

clayey
sandy
stony
silty
loamy
impermeable bedrock
permeable bedrock
unknown

4 average erf size is

less than 500 sq.m.
between 500 and 1000 sq.m.
more than 1000 sq.m.

5 the highest seasonal level of groundwater table is

above ground
within 0,3m.of surface
between 0,3m. and 2,0m. of surface
between 2m. and 3m. of surface.
between 3m. and 4m. of surface.
between 4m.and 10m. of surface
below 10m.
unknown

6 the type of water feature is

a seasonal stream or river
a perennial stream or river
a coastal lake
a vlei or stagnant portion of an estuary
an estuary,open to the sea all year
an estuary,open to the sea for more than six months per year
an estuary,open to the sea seasonally only
an estuary, open to the sea occasionally
the seashore
other

7 shortest distance to the water feature boundary is

less than 10m.
between 10 & 30m.
between 30 & 50m.
between 50 & 100m.
between 100 & 300m.
more than 300m.

CHOICES:

1 No significant impact from the proposed sewage disposal is foreseen.

2 Some impact from the proposed method of sewage disposal is likely. However,if the mitigating measures are investigated and applied according to expert specifications, results should be cost-effective.

3 A major impact on groundwater quality is likely.

4 Eutrophication of surface waters and the presence of scum,putrid sediments,disease vectors and aquatic plant infestations are likely to occur in and around the surface water feature.

5 Septic tank effluent could come to the surface,resulting in the presence of scum,bad odours,disease vectors,etc.,in certain locations such as in dips and hollows,seepage areas ,etc.

6 Consider alternative means of sewage disposal.

7 Obtain expert advice on soil suitability and the possible negative effects resulting from a high groundwater level.

8 Obtain expert advice on the extent of possible pollution of the groundwater aquifer from percolating effluent.

9 Obtain expert advice on the hazard potential of sewage effluent from the proposed development on the surface water feature in question.

VARIABLES:

1 DISPOSAL NOTE
Investigate possibility of creating a built-up soakage field that is planted to suitable vegetation which is efficient at taking up phosphates, nitrates and water from the soil.
Displayed at the end of a run as text only
Displayed at the end of a run

2 SUGGEST
Suggestion :- Use a storage container or else connect to an authorized sewage disposal system.
Displayed at the end of a run as text only
Displayed at the end of a run

3 EUTROPHICATION
The likelihood of eutrophication occurring- variable used to transfer data
Numeric variable
Initialized to 0.000000

A P P E N D I X - V

P H Y S R E C : R U L E S, Q U A L I F I E R S, C H O I C E S A N D V A R I A B L E S

Subject:

The determination of upper limits to physical recreational resource use for a water surface feature.

Starting text:
Surface water features are limited in water area suitable for different types of recreational activity. This module examines spatial reqirements for each activity and development trends in the vicinity.Recreational suitability and probability of congestion are output.

Ending text:
Note: Advice given is on recreational unsuitability an present and future congestion of the craft,or activity, question. Values from 1 to 10 indicate the likelihood of the advice being correct. Extra notes are often appended for information.

.....

RULES:

RULE NUMBER: 1

IF:

recreation considered for the water surface area in question is powerboating or yachting or boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [60 CM DEEP AREA]<0.05

THEN:

Space requirements make the area in question unsuitable for skiing. - Probability=10/10

and Space requirements make the area in question unsuitable for powerboats. - Probability=10/10

and space requirements make the area in question unsuitable for yachts. - Probability=10/10

and Space requirements make the area in question unsuitable for sailboards. - Probability=9/10

NOTE:
Minimum average space requirements for sailboards is 0,1 hectare (1000sq.m.) per craft.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J. Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 2

IF:
recreation considered for the water surface area in question is powerboating or yachting or boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [60 CM DEEP AREA]>=0.05
and [60 CM DEEP AREA]<.1

THEN:
Space requirements make the area in question unsuitable for skiing. - Probability=10/10

and Space requirements make the area in question unsuitable for powerboats. - Probability=10/10

and Space requirements make the area in question unsuitable for yachts. - Probability=9/10

and Space requirements make the area in question unsuitable for sailboards. - Probability=5/10

NOTE:
Minimum average space requirements for skiing,powerboating,yachting and boardsailing are not met.However, as boardsailing is just below its recommended requirement of 0,1 ha (1000 sq.m.) per craft, there should be instances when this does not apply.
Contact specialists for further advice, e.g.:
Environmental Evaluation Unit, U.C.T.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J. Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 3

IF:
recreation considered for the water surface area in question is powerboating or yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [60 CM DEEP AREA]>=0.1
and [60 CM DEEP AREA]<.5
and [1M DEEP AREA]<0.1

THEN:
Space requirements make the area in question unsuitable for skiing. - Probability=10/10

and Space requirements make the area in question unsuitable for powerboats. - Probability=10/10

and Space requirements make the area in question unsuitable for yachts. - Probability=7/10

and Note: the area may be suitable for small yachts.

NOTE:
Minimum average space requirements for skiing,powerboating and yachting are not met.However, if small yachts of shallow draught are considered, there should be instances when these requirements do not apply.
Contact specialists for further advice,e.g.:
Environmental Evaluation Unit, U.C.T.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J.Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 4

IF:
recreation considered for the water surface area in question is powerboating or yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [1M DEEP AREA]>=0.1
and [1M DEEP AREA]<.5

THEN:

Space requirements make the area in question unsuitable for skiing. - Probability=10/10

and Space requirements make the area in question unsuitable for powerboats. - Probability=8/10

and Space requirements make the area in question unsuitable for yachts. - Probability=5/10

and Note: the area may be suitable for small yachts.

NOTE:
Minimum average space requirements for skiing,powerboating and yachting are not met.However, if small yachts are considered, there should be instances when these requirements do not apply.
Contact specialists for further advice, e.g.:
Environmental Evaluation Unit, U.C.T.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J.Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 5

IF:

recreation considered for the water surface area in question is powerboating or yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [1M DEEP AREA]>=0.5
and [1M DEEP AREA]<1.2

THEN:

Space requirements make the area in question unsuitable for skiing. - Probability=10/10

and Space requirements make the area in question unsuitable for powerboats. - Probability=6/10

and Space requirements make the area in question unsuitable for yachts. - Probability=2/10

and Note : If powered craft are to be considered, then limits on speed, size and/or power may be needed.

and Note : Limits on the size of yachts might be needed.

NOTE:
(1) Minimum average space requirements for skiing and powerboating are not met.However, as powerboating is just below the recommended requirements, there should be instances when these need not apply.
(2) Yachts may need up to 1ha per craft.
(3) Contact specialists for further advice, e.g.:
Environmental Evaluation Unit, U.C.T.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J. Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 6

IF:

recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [1M DEEP AREA]>=1.2
and [1M DEEP AREA]<4

THEN:

Space requirements make the area in question unsuitable for skiing. - Probability=9/10

and Space requirements make the area in question unsuitable for powerboats. - Probability=2/10

and Note : If powered craft are to be considered, then limits on speed, size and/or power may be needed.

NOTE:
(1) Minimum average space requirements for skiing are not met.
(2) Even though space requirements for powerboating are met, suitable restrictions on speed,boat size,and engine power may still need to be applied.
(3) Contact specialists for further advice, e.g.: Environmental Evaluation Unit, U.C.T.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J.Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 7

IF:
recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [1M DEEP AREA]>=4
and [1M DEEP AREA]<8

THEN:
Space requirements make the area in question unsuitable for skiing. - Probability=6/10

NOTE:
Space requirements for skiing are between 8 and 16 ha for a boat-rig-skier.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J. Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 8

IF:
recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [1M DEEP AREA]>=8
and [1M DEEP AREA]<16

THEN:
Space requirements make the area in question unsuitable for skiing. - Probability=3/10

NOTE:
Skiing requirements are between 8 and 16 hectare for each boat-rig-skier.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J. Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 9

IF:
recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PBOATS ON WATER]>=1

THEN:
[P CONGESTION FACTOR] IS GIVEN THE VALUE [PBOATS ON WATER]*4/[1M DEEP AREA]

NOTE:
The congestion factor is the ratio:-
The water surface area required for safe use by the number and type of craft concerned
DIVIDED BY
the water surface area available for their use.

REFERENCE:
Sowman,M.R. and Fuggle,R.F., 1986: Assessing Recreational Carrying Capacity: A Case Study of the Kromme River Estuary, South Africa., J. Shoreline Management, Vol.3, Pp 53-75

RULE NUMBER: 10

IF:

recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [P CONGESTION FACTOR]>=1

THEN:

Congestion by powerboats (on their own) of the area in question is likely to occur in present conditions. - Probability=6/10

RULE NUMBER: 11

IF:

recreation considered for the water surface area in question is yachting and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary,open to the sea seasonally only or an estuary, open to the sea occasionally

and [YACHTS ON WATER]>=1

THEN:

[Y CONGESTION FACTOR] IS GIVEN THE VALUE [YACHTS ON WATER]*0.5/[1M DEEP AREA]

NOTE:
Y CONGESTION FACTOR (water surface area required for safe use by the present maximum number of yachts) DIVIDED BY (area available for their use)

RULE NUMBER: 12

IF:

recreation considered for the water surface area in question is yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [Y CONGESTION FACTOR]>=1

THEN:

Congestion by yachts (on their own) is likely to occur. - Probability=6/10

RULE NUMBER: 13

IF:

recreation considered for the water surface area in question is boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, to the sea occasionally

and [BOARDSAILS ON WATER]>=1

THEN:

[S CONGESTION FACTOR] IS GIVEN THE VALUE [BOARDSAILS ON WATER]*0.1/ [60 CM DEEP AREA]

NOTE:
S CONGESTION FACTOR (the water surface area required for safe use by the present maximum number of sailboards) DIVIDED BY (the water surface area available for their use.)

RULE NUMBER: 14

IF:

recreation considered for the water surface area in question is boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [S CONGESTION FACTOR]>=1

THEN:

Congestion by sailboards,on their own,is likely to occur in present conditions. - Probability=6/10

RULE NUMBER: 15

IF:

recreation considered for the water surface area in question is powerboating and yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PRESENT YACHTS]>=1
and [PRESENT POWERBOATS]>=1

THEN:

[PY CONGESTION FACTOR] IS GIVEN THE VALUE ([PRESENT YACHTS]*.5+[PRESENT POWERBOATS]*4)/[1M DEEP AREA]

NOTE:
PY CONGESTION FACTOR (the water surface area required for safe use by the present maximum number of powerboats and yachts together) DIVIDED BY (the area available for their use)

RULE NUMBER: 16

IF:

recreation considered for the water surface area in question is powerboating and yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PY CONGESTION FACTOR]>=1

THEN:

Congestion by powerboats and yachts together is likely to occur in present conditions. - Probability=6/10

RULE NUMBER: 17

IF:

recreation considered for the water surface area in question is yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PRESENT BOARDSAILS]>=1
and [PRESENT YACHTS]>=1

THEN:

[SY CONGESTION FACTOR] IS GIVEN THE VALUE ([PRESENT YACHTS]*.5+[PRESENT BOARDSAILS]*.1)/[60 CM DEEP AREA]

NOTE:
SY CONGESTION FACTOR (the water surface area required for safe use by the present maximum number of sailboards and yachts together) DIVIDED BY (the area available for their use)

RULE NUMBER: 18

IF:

recreation considered for the water surface area in question is yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary,

open to the sea seasonally only or an estuary, open to the sea occasionally

and [SY CONGESTION FACTOR]>=1

THEN:

Congestion by yachts and sailboards together is likely to occur in present conditions. - Probability=6/10

RULE NUMBER: 19

IF:

recreation considered for the water surface area in question is powerboating and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PRESENT POWERBOATS]>=1
and [PRESENT BOARDSAILS]>=1

THEN:

[SP CONGESTION FACTOR] IS GIVEN THE VALUE ([PRESENT POWERBOATS]*4+[PRESENT BOARDSAILS]*.1)/[60 CM DEEP AREA]

NOTE:
SP CONGESTION FACTOR (the water surface area required for safe use by the present maximum number of sailboards and powerboats together) DIVIDED BY (the area available for their use)

RULE NUMBER: 20

IF:

recreation considered for the water surface area in question is powerboating and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [SP CONGESTION FACTOR]>=1

THEN:

Congestion by powerboats and sailboards is likely to occur in present conditions. - Probability=6/10

RULE NUMBER: 21

IF:

recreation considered for the water surface area in question is powerboating,yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PRESENT POWERBOATS]>=1
and [PRESENT BOARDSAILS]>=1
and [PRESENT YACHTS]>=1

THEN:

[PYS CONGESTION FACTR] IS GIVEN THE VALUE ([PRESENT POWERBOATS] * 4 + [PRESENT YACHTS] * .5 + [PRESENT BOARDSAILS] * .1) / [60 CM DEEP AREA]

NOTE:
PYS CONGESTION FACTOR (the water surface area required for safe use by the present maximum number of powerboats, yachts and sailboards together) DIVIDED BY (the area available for their use)

RULE NUMBER: 22

IF:

recreation considered for the water surface area in question is powerboating,yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and [PYS CONGESTION FACTR]>=1

THEN:

Congestion by powerboats,yachts and sailboards together is likely to occur in present conditions. - Probability=6/10

RULE NUMBER: 23

IF:

land in the vicinity of the surface water feature in question is partially developed

THEN:

[LOW PROPORTION] IS GIVEN THE VALUE ([PRESENT ERVEN NO]*[CONST]+ [LOW EST EXTRA])/([BUILT ERVEN NO]*[CONST]+[EXTRA])

NOTE:
LOW PROPORTION is the ratio (the peak holiday population estimate to occur when all existing erven are fully developed) DIVIDED BY (present peak holiday population estimate)

RULE NUMBER: 24

IF:

land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

THEN:

[HIGH PROPORTION] IS GIVEN THE VALUE (([PRESENT ERVEN NO] + [PROPOSED ERVEN]) * [CONST] + [HIGH EST EXTRA])/([BUILT ERVEN NO]*[CONST]+[EXTRA])

NOTE:
HIGH PROPORTION is the ratio (the estimate of the peak holiday population occurring in the vicinity at the time when all erven, including those proposed, are fully developed) DIVIDED BY (the present peak holiday population estimate)

RULE NUMBER: 25

IF:

recreation considered for the water surface area in question is NOT other than powerboating,yachting or boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [P CONGESTION FACTOR]*[HIGH PROPORTION]<1

and [Y CONGESTION FACTOR]*[HIGH PROPORTION]<1

and [S CONGESTION FACTOR]*[HIGH PROPORTION]<1

and [PY CONGESTION FACTOR]*[HIGH PROPORTION]<1

and [SP CONGESTION FACTOR]*[HIGH PROPORTION]<1

and [SY CONGESTION FACTOR]*[HIGH PROPORTION]<1

and [PYS CONGESTION FACTR]*[HIGH PROPORTION]<1

THEN:

the water surface area is not likely to be congested by the craft in question when all erven,including those proposed, are built up - Probability=6/10

RULE NUMBER: 26

IF:

recreation considered for the water surface area in question is NOT other than powerboating,yachting or boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [P CONGESTION FACTOR]*[LOW PROPORTION]<1

and [Y CONGESTION FACTOR]*[LOW PROPORTION]<1

and [S CONGESTION FACTOR]*[LOW PROPORTION]<1

and [PY CONGESTION FACTOR]*[LOW PROPORTION]<1

and [SP CONGESTION FACTOR]*[LOW PROPORTION]<1

and [SY CONGESTION FACTOR]*[LOW PROPORTION]<1

and [PYS CONGESTION FACTR]*[LOW PROPORTION]<1

THEN:

the water surface area is not likely to be congested by the craft in question when all presently available erven are built up. - Probability=6/10

RULE NUMBER: 27

IF:

recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [P CONGESTION FACTOR]*[LOW PROPORTION]>=1

THEN:

congestion by powerboats, on their own, of the area in question is likely to occur when all present erven are fully developed -Probability=7/10

RULE NUMBER: 28

IF:

recreation considered for the water surface area in question is yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [Y CONGESTION FACTOR]*[LOW PROPORTION]>=1

THEN:

congestion by yachts, on their own, is likely to occur when all present erven are fully developed - Probability=7/10

RULE NUMBER: 29

IF:

recreation considered for the water surface area in question is boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [S CONGESTION FACTOR]*[LOW PROPORTION]>=1

THEN:

Congestion by sailboards, on their own, is likely to occur when all present erven are fully developed - Probability=7/10

RULE NUMBER: 30

IF:

recreation considered for the water surface area in question is powerboating and yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [PY CONGESTION FACTOR]*[LOW PROPORTION]>=1

THEN:

Congestion by powerboats and yachts together is likely to occur when all present erven are fully developed - Probability=7/10

RULE NUMBER: 31

IF:

recreation considered for the water surface area in question is powerboating and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [SP CONGESTION FACTOR]*[LOW PROPORTION]>=1

THEN:

Congestion by powerboats and sailboards is likely to occur when all present erven are fully developed - Probability=7/10

RULE NUMBER: 32

IF:

recreation considered for the water surface area in question is yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [SY CONGESTION FACTOR]*[LOW PROPORTION]>=1

THEN:

Congestion by yachts and sailboards together is likely to occur when all present erven are fully developed - Probability=7/10

RULE NUMBER: 33

IF:

recreation considered for the water surface area in question is powerboating,yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and [PYS CONGESTION FACTR]*[LOW PROPORTION]>=1

THEN:

Congestion by powerboats,yachts and sailboards together is likely to occur when all present erven are fully developed - Probability=7/10

RULE NUMBER: 34

IF:

recreation considered for the water surface area in question is powerboating

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [P CONGESTION FACTOR]*[HIGH PROPORTION]>=1

THEN:

Congestion by powerboats, on their own, of the area in question is likely to occur when all erven, including those proposed, are fully developed - Probability=8/10

RULE NUMBER: 35

IF:

recreation considered for the water surface area in question is yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [Y CONGESTION FACTOR]*[HIGH PROPORTION]>=1

THEN:

Congestion by yachts, on their own, of the area in question is likely to occur when all erven, including those proposed, are fully developed- Probability=8/10

RULE NUMBER: 36

IF:

recreation considered for the water surface area in question is boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [S CONGESTION FACTOR]*[HIGH PROPORTION]>=1

THEN:

Congestion by sailboards, on their own, of the area in question is likely to occur when all erven, including those proposed, are fully developed - Probability=8/10

RULE NUMBER: 37

IF:

recreation considered for the water surface area in question is powerboating and yachting

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [PY CONGESTION FACTOR]*[HIGH PROPORTION]>=1

THEN:

Congestion by powerboats and yachts together is likely to occur when all erven, including those proposed, are fully developed - Probability=8/10

RULE NUMBER: 38

IF:

recreation considered for the water surface area in question is yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [SY CONGESTION FACTOR]*[HIGH PROPORTION]>=1

THEN:

Congestion by yachts and sailboards together is likely to occur when all erven, including those proposed, are fully developed - Probability=8/10

RULE NUMBER: 39

IF:

recreation considered for the water surface area in question is powerboating and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [SP CONGESTION FACTOR]*[HIGH PROPORTION]>=1

THEN:

Congestion by powerboats and sailboards together is likely to occur when all erven, including those proposed, are fully developed - Probability=8/10

RULE NUMBER: 40

IF:

recreation considered for the water surface area in question is powerboating,yachting and boardsailing

and the type of surface water feature is a coastal lake or a vlei or stagnant portion of an estuary or an estuary, open to the sea all year or an estuary, open to the sea for more than six months or an estuary, open to the sea seasonally only or an estuary, open to the sea occasionally

and land in the vicinity of the surface water feature in question is partially developed

and the proposal is to essentially put more erven on the market or to expand present residential facilities

and [PYS CONGESTION FACTR]*[HIGH PROPORTION]>=1

THEN:

Congestion by powerboats, yachts and sailboards together is likely to occur when all erven, including those proposed, are fully developed. - Probability=8/10

RULE NUMBER: 41

IF:

recreation considered for the water surface area in question is NOT other than powerboating,yachting or boardsailing

and [P CONGESTION FACTOR]<1

and [Y CONGESTION FACTOR]<1

and [S CONGESTION FACTOR]<1

and [PY CONGESTION FACTOR]<1

and [SP CONGESTION FACTOR]<1

and [PYS CONGESTION FACTR]<1

THEN:

the water surface area is not congested in present conditions by the craft in question - Probability=6/10

RULE NUMBER: 42

IF:

[P CONGESTION FACTOR]>0

THEN:

[HI CONG FACTOR] IS GIVEN THE VALUE [P CONGESTION FACTOR]*[HIGH PROPORTION]

and [PBOATS RELEVANT] IS GIVEN THE VALUE 1

RULE NUMBER: 43

IF:
[Y CONGESTION FACTOR]>0

THEN:
[HI CONG FACTOR] IS GIVEN THE VALUE [Y CONGESTION FACTOR]*[HIGH PROPORTION]

RULE NUMBER: 44

IF:
[S CONGESTION FACTOR]>0

THEN:
[HI CONG FACTOR] IS GIVEN THE VALUE [S CONGESTION FACTOR]*[HIGH PROPORTION]

RULE NUMBER: 45

IF:
[PY CONGESTION FACTOR]>0

THEN:
[HI CONG FACTOR] IS GIVEN THE VALUE [PY CONGESTION FACTOR]*[HIGH PROPORTION]

and [PBOATS RELEVANT] IS GIVEN THE VALUE 1

RULE NUMBER: 46

IF:
[SY CONGESTION FACTOR]>0

THEN:
[HI CONG FACTOR] IS GIVEN THE VALUE [SY CONGESTION FACTOR]*[HIGH PROPORTION]

RULE NUMBER: 47

IF:
[SP CONGESTION FACTOR]>0

THEN:
[HI CONG FACTOR] IS GIVEN THE VALUE [SP CONGESTION FACTOR]*[HIGH PROPORTION]

and [PBOATS RELEVANT] IS GIVEN THE VALUE 1

RULE NUMBER: 48

IF:
[PYS CONGESTION FACTR]>0

THEN:
[HI CONG FACTOR] IS GIVEN THE VALUE [PYS CONGESTION FACTR]*[HIGH PROPORTION]

and [PBOATS RELEVANT] IS GIVEN THE VALUE 1

QUALIFIERS:

1 recreation considered for the water surface area in question is

powerboating
yachting
boardsailing
powerboating and yachting
yachting and boardsailing
powerboating and boardsailing
powerboating,yachting and boardsailing
other than powerboating,yachting or boardsailing

2 the type of surface water feature is

a seasonal stream or river
a perennial stream or river
a coastal lake
a vlei or stagnant portion of an estuary
an estuary, open to the sea all year
an estuary, open to the sea for more than six months
an estuary, open to the sea seasonally only
an estuary, open to the sea occasionally
the seashore(sandy beach)
the seashore,other.

3 present recreation is

powerboating
yachting
boardsailing
rowing
swimming
angling
other

4 land in the vicinity of the surface water feature in question is

undeveloped - no erven available
partially developed
developed

5 the proposal is

to essentially put more erven on the market
to increase the population density by rezoning or otherwise
to expand present residential facilities
to expand or to add recreational facilities
other

CHOICES:

1 Space requirements make the area in question unsuitable for skiing.

2 Space requirements make the area in question unsuitable for powerboats.

3 Space requirements make the area in question unsuitable for yachts.

4 Space requirements make the area in question unsuitable for sailboards.

5 Congestion by powerboats (on their own) of the ar.. in question is likely to occur in present conditions.

6 Congestion by yachts (on their own) is likely to occur.

7 Congestion by sailboards,on their own,is likely to occur in present conditions.

8 Congestion by powerboats and yachts together is likely to occur in present conditions.

9 Congestion by yachts and sailboards together is likely to occur in present conditions.

10 Congestion by powerboats,yachts and sailboards together is likely to occur in present conditions.

11 Congestion by powerboats and sailboards is likely to occur in present conditions.

12 the water surface area is not congested in present conditions by the craft in question

13 the water surface area is not likely to be congested by the craft in question when all presently available erven are built up.

14 the water surface area is not likely to be congested by the craft in question when all erven,including those proposed, are built up

15 congestion by powerboats, on their own, of the area in question is likely to occur when all present erven are fully developed

16 congestion by yachts, on their own, is likely to occur when all present erven are fully developed

17 Congestion by sailboards, on their own, is likely to occur when all present erven are fully developed

18 Congestion by powerboats and yachts together is likely to occur when all present erven are fully developed

19 Congestion by powerboats and sailboards is likely to occur when all present erven are fully developed

20 Congestion by yachts and sailboards together is likely to occur when all present erven are fully developed

21 Congestion by powerboats,yachts and sailboards together is likely to occur when all present erven are fully developed

22 Congestion by powerboats, on their own, of the area in question is likely to occur when all erven, including those proposed,are fully developed

23 Congestion by yachts, on their own, of the area in question is likely to occur when all erven, including those proposed, are fully developed

24 Congestion by sailboards, on their own, of the area in question is likely to occur when all erven, including those proposed, are fully developed

25 Congestion by powerboats and yachts together is likely to occur when all erven, including those proposed, are fully developed

26 Congestion by yachts and sailboards together is likely to occur when all erven, including those proposed, are fully developed

27 Congestion by powerboats and sailboards together is likely to occur when all erven, including those proposed, are fully developed

28 Congestion by powerboats, yachts and sailboards together is likely to occur when all erven, including those proposed, are fully developed.

29 the craft in question do not use the water area at present

VARIABLES:

1 P CONGESTION FACTOR
Powerboat congestion factor for powerboats on their own,in present conditions
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

2 60 CM DEEP AREA
the surface area of water which has a depth of 0,6m or more (hectares).
Numeric variable

3 1M DEEP AREA
the surface area of water which has a depth of one metre or more.
Numeric variable

4 SMALL YACHTS
Note: the area may be suitable for small yachts.
Displayed at the end of a run as text only
Displayed at the end of a run

5 SPEED LIMITS
Note : If powered craft are to be considered, then limits on speed, size and/or power may be needed.
Displayed at the end of a run as text only
Displayed at the end of a run

6 LARGE YACHTS
Note : Limits on the size of yachts might be needed.
Displayed at the end of a run as text only
Displayed at the end of a run

7 PBOATS ON WATER
the maximum number of powerboats using the area in question at any one time in present conditions.
Numeric variable

8 Y CONGESTION FACTOR
The yacht congestion factor for yachts on their own, in present conditions
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

9 YACHTS ON WATER
the maximum number of yachts using the area in present conditions.
Numeric variable

10 BOARDSAILS ON WATER
the maximum of sailboards using the area in present conditions.
Numeric variable

11 S CONGESTION FACTOR
Sailboard congestion factor, for sailboards on their own, in present conditions
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

12 PRESENT BOARDSAILS
the number of sailboards present when maximum use of the water surface is being made by the types of craft in question
Numeric variable

13 PRESENT YACHTS
the number of yachts present when maximum use of the water surface is being made by the types of craft in question.
Numeric variable

14 PRESENT POWERBOATS
the number of powerboats present when maximum use of the water surface is being made by the types of craft in question.
Numeric variable

15 PY CONGESTION FACTOR
The congestion factor of both powerboats and yachts when they are making maximum use of the water surface area together, in present conditions.
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

16 SY CONGESTION FACTOR
The congestion factor of both sailboards and yachts,taken together, in present conditions
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

17 SP CONGESTION FACTOR
The congestion factor of both powerboats and sailboards, taken together, in present conditions
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

18 PYS CONGESTION FACTR
The congestion factor of powerboats, yachts and sailboards taken together, in present conditions
Numeric variable
Displayed at the end of a run
Initialized to 0.000000

19 LOW PROPORTION
the ratio (population estimate with all present erven built up) DIVIDED BY (present population estimate)
Numeric variable
Initialized to 1.000000

20 PRESENT ERVEN NO
all single residential ervem in the vicinity at present
Numeric variable

21 BUILT ERVEN NO
the number of erven in the vicinity, with houses on them, at present
Numeric variable

22 CONST
the estimate of the average number of people per house during high holiday season
Numeric variable
Initialized to 6.500000

23 EXTRA
the estimate of the number of people who PRESENTLY occupy other accomodation during high holiday season
Numeric variable

24 LOW EST EXTRA
estimate of the number of occupants living in other accomodation during peak holiday season at the time when all presently available erven are fully developed
Numeric variable

25 HIGH PROPORTION
the ratio (the peak holiday population estimate with proposed development) DIVIDED BY (the peak holiday population estimate at present)
Numeric variable
Initialized to 1.000000

26 PROPOSED ERVEN
the number of single residential erven planned for in the development proposal
Numeric variable

27 HIGH EST EXTRA
estimate of the number of occupants living in other accomodation during the peak holiday period when all the present and proposed erven are fully developed
Numeric variable

28 NO CRAFT USE
no relevant craft use the area in question
Numeric variable
Initialized to 0.000000

29 HI CONG FACTOR
the recreational congestion factor multiplied by the ratio HIGH PROPORTION
Numeric variable

30 PBOATS RELEVANT
this variable is to be used to communicate the knowledge that powerboats use the area in question to GENREC
Numeric variable
Initialized to 0.000000

APPENDIX VI

AVIREC: RULES, QUALIFIERS, CHOICES AND VARIABLES

Subject:
The determination of restrictions for water-based recreation, based on sensitive environmental components (birds and their habitat).

Starting text:
This module examines:

(1) the sensitivity of each bird species to different recreational uses (at present, to powerboating, yachting and boardsailing)

(2) the endangered status of the species (Red Data Book).

(3) the number of species and number of individual birds

(4) the size of the wetland area, habitat diversity, amongst others.

Habitat diversity is input from the user or the "blackboard" file. Habitat naturalness and threat of human disturbance are not presently addressed. The "PERIOD IN QUESTION" referred to in the rules is that over which recreation is being considered (for example, the summer holiday season).

RULES:

RULE NUMBER: 1

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the value of the area as a habitat for the bird(s) in question is unknown (of unknown importance for the bird(s))

THEN:
contact bird specialists for further advice. Probability=10/10

and review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations). - Probability=10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

NOTE:
The importance of the the surface water feature as a habitat for birds needs to be assessed before advice on recreational management options is sought.

REFERENCE:
Dr.P.A.R.Hockey, U.C.T.

RULE NUMBER: 2

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is unknown

THEN:
contact bird specialists for further advice. - Probability=10/10

and review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations). - Probability=10/10

and identify birds with the help of a specialist and, if needed, an identification manual. - Probability=10/10

and For bird specialists,contact :P .G .Ryan, R. K. Brooke, P. A. R. Hockey : Ornithology, University of CapeTown,Private Bag,Rondebosch,CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

RULE NUMBER: 3

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the value of the area as a habitat for the bird(s) in question is considered to be high (i.e. important)

THEN:

Investigate the feasibility of giving the surface water feature some conservation status (see further details) - Probability=10/10

and review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations). - Probability=10/10

and contact bird specialists for further advice. - Probability=10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

and Protection of the bird habitat may be effected by:
(1) Registration under the RAMSAR CONVENTION as being of international importance.
(2) Being proclaimed as, or included in, a NATIONAL PARK (Nat. Parks Act, 1957) ; a Provincial, Municipal, or private nature reserve ; a nature reserve or Wilderness Area (Forest Act ,1968) ; or a Nature Area (Env. Cons. Act,1982)

NOTE:
IF A NATURAL SURFACE WATER FEATURE IS AN IMPORTANT HABITAT FOR BIRDS, SOME CONSERVATION STATUS FOR THE HABITAT AND ITS ENVIRONS IS NORMALLY RECOMMENDED.

REFERENCE:
Hockey, P.A.R., 1987 : Pers. Comm.
Fuggle, R.F. & Rabie,M.A., 1983: ENVIRONMENTAL CONCERNS IN S.A.

RULE NUMBER: 4

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present

THEN:

contact bird specialists for further advice. - Probability=10/10b

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

NOTE:
If a large number of birds are present during,or just before, the period in question, specialist advice on management alternatives may be needed.

REFERENCE:
Hockey.,P.A.R. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 5

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Spurwing Goose or Egyptian Goose or Cape Shoveller or Yellowbill Teal or Redbill Teal or Cape Teal

THEN:

the name of the bird in question is any duck or goose (Anatidae)

NOTE:
Anatidae (duck and goose) species listed here have similar reactions to different types of disturbance, and are treated together for this purpose.

REFERENCE:
Taylor.,M. 1987: pers.comm
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 6

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity
and just before, or during, the period in question, there have been only one or two individuals present

THEN:

yachts should be kept away from the breeding/ roosting area during the period specified (see further details) - Probability=1/10

REFERENCE:
Taylor.,M. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 7

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Redknobbed Coot
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))

THEN:

review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations). -Probability=10/10

and the area could be an important habitat for the birds in question. - Probability=4/10

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

NOTE:
The importance of a habitat to a species of bird is dependent, in part,on the species itself and on the number of individuals making use of the habitat.
REF: Taylor,M., 1987: Pers Comm.

RULE NUMBER: 8

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity
and just before, or during, the period in question, there have been only one or two individuals present

THEN:

sailboards and their occupants should be kept away from the breeding/roosting area during the period specified (see further details) - Probability=3/10

NOTE:
Boardsailors can access certain areas and beach their craft where other craft cannot.These include breeding/ roosting areas for birds such as Coot.

REFERENCE:
Taylor.,M. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVI[illegible] ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 9

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))

and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity
and just before, or during, the period in question, there have been many individuals present

THEN:

the area could be an important habitat for the birds in question. - Probability=7/10

NOTE:
The importance of a habitat to a species of bird is dependent,in part, on the species itself ,the number of individuals making use of the habitat and on the type of use made.

REFERENCE:
Rowlands,B.W. 1987: PERS. COMM.
Taylor.,M. 1987: pers.comm.

RULE NUMBER: 10

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity
and just before, or during, the period in question, there have been only one or two individuals present

THEN:

powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) - Probability=6/10

NOTE:
Roosting Coot are very sensitive to wave set-up or wash along the shore. Breeding coot make nests of floating vegetation/debris. These nests are extremely vulnerable to unusual waves.

REFERENCE:
Taylor.,M. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 11

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity
and just before, or during, the period in question, there have been several individuals present

THEN:

powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) - Probability=7/10

NOTE:
Roosting Coot are very sensitive to wave set-up or wash along the shore. Breeding coot make nests of floating vegetation/debris.These nests are extremely vulnerable to unusual waves.

REFERENCE:
Taylor.,M. 1987: pers.comm
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 12

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been several individuals present
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity

THEN:

sailboards and their occupants should be kept away from the breeding/roosting area during the period specified (see further details) - Probability=6/10

NOTE:
Boardsailors can access certain areas and beach their craft where other craft cannot. These include breeding/ roosting areas for birds such as Coot.

REFERENCE:
Taylor.,M. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 13

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity

THEN:
sailboards and their occupants should be kept away from the breeding/roosting area during the period specified (see further details) - Probability=9/10

and contact bird specialists for further advice. - Probability=9/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

NOTE:
Boardsailors can access certain areas and beach their craft where other craft cannot.These include breeding/ roosting areas for birds such as Coot.

REFERENCE:
Taylor.,M. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 14

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity

THEN:
yachts should be kept away from the breeding/ roosting area during the period specified (see further details) - Probability=7/10

and contact bird specialists for further advice. - Probability=7/10

and For bird specialists, contact :P. G. Ryan P. K. Brooke, P. A. R. Hockey :Ornithology, Univers[illegible] of Cape Town, Private Bag, Rondebosch, CAPE TOW[illegible]00 Phone: (021)-6509111

RULE NUMBER: 15

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been several individuals present
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity

THEN:
yachts should be kept away from the breeding / roosting area during the period specified (see further details) - Probability=4/10

RULE NUMBER: 16

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity or breeding in the vicinity

THEN:

apply speed limits to powered craft in the vicinity during the period in question. - Probability=9/10

and powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) - Probability=9/10

and contact bird specialists for further advice. - Probability=9/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

NOTE:
Roosting Coot are very sensitive to wave set-up and to wash along the shore. Breeding Coot make nests of floating vegetation/ debris. These nests are extremely vulnerable to unusual waves or physical disturbance.
REFERENCE:
Taylor.,M. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 17

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Redknobbed Coot
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been NOT many individuals present

and just before, or over, the period in question the birds have been present, but not roosting or breeding

THEN:

apply speed limits to powered craft in the vicinity during the period in question. - Probability=5/10

NOTE:
When on open water,Coot move aside for slower craft. Powered craft moving at speed tend to flush the birds.

REFERENCE:
Taylor., M. 1987: pers.comm.

RULE NUMBER: 18

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Redknobbed Coot
and just before, or over, the period in question the birds have been present, but not roosting or breeding
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present

THEN:

apply speed limits to powered craft in the vicinity during the period in question. - Probability=8/10

NOTE:
When on open water,Coot move aside for slower craft. Powered craft moving at speed tend to flush the birds.

REFERENCE:
Hockey.,P.A.R. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 19

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Darter
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))

THEN:

review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations). - Probability=10/10

and the area could be an important habitat for the birds in question. - Probability=6/10

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

NOTE:
The importance of a habitat to a species of bird is dependent on the species itself and on the number of individuals making use of the habitat.

REFERENCE:
Taylor,M., 1987 : Pers. Comm.

RULE NUMBER: 20

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Darter
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been only one or two individuals present or several individuals present

THEN:

limit the number of yachts using the area over the period in question - Probability=5/10

and contact bird specialists for further advice. - Probability=5/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

NOTE:
When on open water,Darter are sensitive to yachts.

REFERENCE:
Taylor.,M., 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 21

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Darter
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present

THEN:

limit the number of yachts using the area over the period in question - Probability=8/10

NOTE:
When on open water,Darter are sensitive to yachts.

REFERENCE:
Hockey.,P.A.R. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 22

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Darter
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or during, the period in question, there have been many individuals present

THEN:

apply speed limits to powered craft in the vi nity during the period in question. - Probability=8/

and consider prohibiting powered craft from using the area - Probability=7/10

and contact a fish specialist for advice on the impact of powered craft on any fish populations present . - Probability=10/10

and Estuarine fish experts are: Bruce Bennet and Glynnis Bleckley,Zoology Dept., University of Cape Town, Private Bag,RONDEBOSCH 7700. Ph:6509111

NOTE:
(1) When on open water,Darter are flushed by approaching powered craft.
(2) The presence of large numbers of Darter could indicate the presence of fish shoals in the surface water feature.

REFERENCE:
Hockey.,P.A.R. 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 23

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Darter
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before or during the period in question, there have been only one or two individuals present or several individuals present

THEN:
limit the number of powerboats using the area over the period in question - Probability=2/10
and apply speed limits to powered craft in the vicinity during the period in question. - Probability=3/10

NOTE:
When on open water,Darter are flushed by approaching powered craft.

REFERENCE:
Taylor.,M., 1987: pers.comm.
Rowlands,B.W. 1983: THE EFFECTS OF RECREATIONAL ACTIVITIES ON AQUATIC AVIFAUNA, unpublished thesis, School of Environmental Studies, University of Cape Town, S.Afr.

RULE NUMBER: 24

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Caspian Tern
and the period in question is January or February or November or December or summer
and just before, or during, the period in question, there have been several individuals present or many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and just before, or over, the period in question the birds have been roosting,but there is uncertainty as to whether they have been breeding

THEN:
the bird in question is breeding in the vicinity. - Probability=9/10

and contact bird specialists for further advice - Probability=10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

NOTE:
Caspian Tern breed in Dec./Jan.in the western Cape. They roost on the banks or slopes around estuaries, or on islands or mudbanks in estuaries or wetlands, provided these sites are undisturbed.

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.
Cooper, J., 1987: pers. comm.

RULE NUMBER: 25

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the period in question is NOT January or February or November or December or summer
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))

and just before, or over, the period in question the birds have been roosting,but there is uncertainty as to whether they have been breeding

THEN:
the bird in question is breeding in the vicinity. - Probability=1/10
and contact bird specialists for further advice. - Probability=10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 26

IF:
the name of the bird in question is Caspian Tern

THEN:
the bird is classified as RARE in the S.Afr.Red Data Book - Birds (Brooke,R.K., 1984)

NOTE:
Species classified as Rare in southern Africa are those whose numbers are reduced to critical levels, or may be extinct.

REFERENCE:
Brooke,R.K. 1984: SOUTH AFRICAN RED DATA BOOK- BIRDS, S.Afr.Nat.Sci.Prog.Report 97., Pretoria

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RULE NUMBER: 27

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))

THEN:
the area could be an important habitat for the birds in question. - Probability=7/10

and review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations). - Probability=10/10

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

NOTE:
The importance of a habitat to a species of bird is dependent, in part,on the species itself and on the number of individuals making use of the habitat.

REFERENCE:
Taylor,M., 1987 : PERS.COMM.

RULE NUMBER: 28

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s)
and just before or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:
the area could be an important habitat for the birds in question. - Probability=9/10

NOTE:
The importance of a habitat to a species of bird is dependent, in part, on the species itself, the number of individuals and the use they are making of the habitat.

REFERENCE:
Taylor,M., 1987: pers. comm.

RULE NUMBER: 29

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been several individuals present or many individuals present
and just before, or over, the period in question the birds have been breeding in the vicinity

THEN:

the area could be an important habitat for the birds in question. - Probability=10/10

NOTE:
The importance of a habitat to a species of bird is dependent, in part, on the species itself, the number of individuals, and the use they are making of the habitat.

REFERENCE:
Taylor,M., 1987 : PERS.COMM.

RULE NUMBER: 30

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Caspian Tern
and just before, or over, the period in question the birds have been breeding in the vicinity

THEN:

sailboards and their occupants should be kept away from the breeding/roosting area during the period specified (see further details) - Probability =9/10

and NOTE: Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

and NOTE: In the western Cape, Caspian Tern breed in Dec./Jan.

NOTE:
Caspian Tern nesting sites are vulnerable to wave wash, physical disturbance and predation.

REFERENCE:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 31

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Caspian Tern
and just before, or over, the period in question the birds have been breeding in the vicinity

THEN:

the area could be an important habitat for the birds in question. - Probability=9/10

and contact bird specialists for further advice. - Probability =10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

NOTE:
(1) When Caspian Terns show signs of starting to breed, disturbance should be kept to a minimum. (2) Caspian Tern is listed as RARE in Brooke (1984)

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 32

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Caspian Tern
and just before or over, the period in question the birds have been breeding in the vicinity

THEN:

yachts should be kept away from the breeding/ roosting area during the period specified (see further details) - Probability=7/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

and NOTE: In the western Cape, Caspian Tern breed in Dec./Jan.

NOTE:
(1) When Caspian Terns show signs of starting to breed, disturbance should be kept to a minimum.
(2) Caspian Tern nesting sites are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 33

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before or over, the period in question the birds have been breeding in the vicinity

THEN:

powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) - Probability=10/10

and consider prohibiting powered craft from using the area - Probability=9/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

and NOTE: In the western Cape, Caspian Tern breed in Dec./Jan.

NOTE:
(1) When Caspian Terns show signs of starting to breed, disturbance should be kept to a minimum.
(2) Caspian Tern nesting sites are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 34

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity
and just before, or during, the period in question, there have been several individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

THEN:

powered craft should be kept well away from the roosting area during the period in question - Probability=8/10

and apply speed limits to powered craft in the vicinity during the period in question. - Probability=8/10

and contact bird specialists for further advice. - Probability=10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 35

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Caspian Tern
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

THEN:

yachts should be kept well away from the roosting area during the period in question - Probability=7/10

and contact bird specialists for further advice. - Probability=9/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Taylor M, 1987: pers. comm.
Hockey,P.A.R., 1987: pers. comm.

RULE NUMBER: 36

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

THEN:

contact a fish specialist for advice on the impact of powered craft on any fish populations present . - Probability=10/10

and Estuarine fish experts are: Bruce Bennet and Glynnis Bleckley, Zoology Dept., University of Cape Town, Private Bag, RONDEBOSCH 7700. Ph:6509111

NOTE:
Small fish are a source of food for Caspian Terns. The presence of large numbers of Caspian Terns may indicate the presence of significant fish populations in the surface water feature in question.

REFERENCES:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 37

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:

sailboards and their occupants should be kept well away from the roosting area during the period in question - Probability=10/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 38

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been only one or two individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:

sailboards and their occupants should be kept well away from the roosting area during the period in question - Probability=6/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 39

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been several individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:

yachts should be kept well away from the roosting area during the period in question - Probability=7/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Tern are sensitive to yachts near their roosting sites.

REFERENCES
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 40

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been only one or two individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:

yachts should be kept well away from the roosting area during the period in question - Probability=4/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE: Caspian Tern are sensitive to yachts near their roosting sites.

REFERENCES
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 41

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is boardsailing
and the name of the bird in question is Caspian Tern
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity
and just before, or during, the period in question, there have been several individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

THEN:

sailboards and their occupants should be kept well away from the roosting area during the period in question - Probability=8/10

and contact bird specialists for further advice. - Probability=9/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 42

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:

consider prohibiting powered craft from using the area - Probability=5/10

and powered craft should be kept well away from the roosting area during the period in question - Probability =10/10

and apply speed limits to powered craft in the vicinity during the period in question. - Probability=9/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks, sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 43

IF:

the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been only one or two individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been roosting (not breeding) in the vicinity

THEN:

powered craft should be kept well away from the roosting area during the period in question - Probability=7/10

and apply speed limits to powered craft in the vicinity during the period in question. - Probability=8/10

and NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.

NOTE:
Caspian Terns,when roosting, are vulnerable to wave wash, physical disturbance and predation.

REFERENCES:
REF: Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 44

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been only one or two individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been present, but not roosting or breeding

THEN:
apply speed limits to powered craft in the vicinity during the period in question. - Probability=2/10

NOTE:
Caspian Tern do not rest (or take refuge) on open water, but skim over it whilst foraging.

REFERENCES:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 45

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been several individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been present, but not roosting or breeding

THEN:
apply speed limits to powered craft in the vicinity during the period in question. - Probability=3/10

NOTE:
Caspian Tern do not rest (or take refuge) on open water, but skim over it whilst foraging.

REFERENCE:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 46

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is Caspian Tern
and just before, or during, the period in question, there have been many individuals present
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)
and just before, or over, the period in question the birds have been present, but not roosting or breeding

THEN:
apply speed limits to powered craft in the vicinity during the period in question. - Probability=8/10

NOTE:
Caspian Tern do not rest (or take refuge) on open water, but skim over it whilst foraging.

REFERENCES:
Hockey,P.A.R., 1987: pers. comm.
Rowlands, B.W., 1987: pers. comm.
Taylor M, 1987: pers. comm.

RULE NUMBER: 47

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is powerboating
and the name of the bird in question is not relevant
and the number of species is,
and the number of species of bird using the area during or just before, the period in question is high
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

THEN:
apply speed limits to powered craft in the vicinity during the period in question. - Probability=9/10

and limit the number of powerboats using the area over the period in question - Probability=9/10

NOTE:
There is a strong inverse relationship between the number of powered craft and the number of species (as well as the total number) of birds present at a surface water feature.The higher the average speed of these craft, the stronger the inverse relationship

REFERENCE:
Rowlands,B.W., 1987: pers. comm.

RULE NUMBER: 48

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and recreation considered for the water surface area in question is yachting or boardsailing
and the name of the bird in question is not relevant, but the number of species is,
and the number of species of bird using the area during or just before, the period in question is high
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important)

THEN:
limit the number of sailing craft using the water surface area over the period in question - Probability=7/10

NOTE:
There is an inverse relationship between the number of sailcraft and the number of species (as well as the total number) of birds resent at a surface water feature.

REFERENCE:
Rowlands,B.W., 1987: pers. comm.

RULE NUMBER: 49

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the name of the bird in question is not relevant, but the number of species is,

and the number of species of bird using the area during or just before, the period in question is high
and wetland habitat diversity is low
and the extent of the wetland associated with the surface water feature is small
and just before, or during, the period in question, there have been NOT many individuals present

THEN:
the area could be an important habitat for the birds in question. - Probability=5/10

and contact bird specialists for further advice. - Probability=10/10

and For bird specialists, contact :P. G. Ryan, R. K. Brooke, P. A. R. Hockey :Ornithology, University of Cape Town, Private Bag, Rondebosch, CAPE TOWN 7700 Phone: (021)-6509111

and NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:Cooper,J. ,Hockey,P.A.R. and Ryan,P.G. 1987/8 : AN ATLAS OF COASTAL BIRDS OF SOUTHERN AFRICA, Percy Fitzpatrick Institute, University of Cape Town. (in press).

NOTE:
The importance of the water surface feature and its environs as a habitat for birds needs to be assessed before advice on recreational management options is sought.

REFERENCE:
Hockey,P.A.R., 1987: pers. comm.

(Notes to Reader:
(1) Other rules could be constructed to determine these and intermediate values more accurately e.g.: IF % wetland is < 10% THEN the extent of the wetland associated with the surface water area is small.
(2) The term "Wetland" needs to be defined in the rules concerned. EXSYS now has a help facility which the expert system developer can use to explain rule functions, terminology used and and other details for the user's benefit.)

RULE NUMBER: 50

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,

THEN:
habitat diversity is relevant to this (specialist) consultation

NOTE:
(1) The conservation potential of a habitat for many species of bird depends on (inter. alia.) the diversity of the habitat
(2) E.S.SYSTEMS NOTE : The qualifier and value in the THEN part of this rule should be passed out to BBFILE for use by the FLOREC module (wetland flora & recreation) ,and a value for wetland habitat diversity returned.

RULE NUMBER: 51

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and habitat diversity is relevant to this consultation
and wetland habitat diversity is high
and the extent of the wetland associated with the surface water feature is large

THEN:
the area could be an important habitat for the birds in question. - Probability=8/10

NOTE:
(1) If the number of species of bird is being addressed, then the estimation of habitat diversity is relevant to this consultation
(2) EXPERT SYSTEMS NOTE : The wetland habitat diversity value is to be passed back from the FLOREC module.

RULE NUMBER: 52

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and habitat diversity is relevant to this consultation
and wetland habitat diversity is high
and the extent of the wetland associated with the surface water feature is small

THEN:
the area could be an important habitat for the birds in question. - Probability=7/10

NOTE:
EXPERT SYSTEMS NOTE : The wetland habitat diversity value is to be passed back from the FLOREC module.

RULE NUMBER: 53

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is Red Knobbed Coot or Darter or Caspian Tern or any duck or goose (Anatidae) or (other)
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the extent of the wetland associated with the surface water feature is large
and just before, or during, the period in question, there have been many individuals present

THEN:
the area could be an important habitat for the birds in question. - Probability=8/10

RULE NUMBER: 54

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(
and the number of species of bird using the area during, or just before, the period in question is high
and just before, or during, the period in question, there have been many individuals present
and wetland habitat diversity is high
and the extent of the wetland associated with the surface water feature is large

THEN:
the area could be an important habitat for the birds in question. - Probability=10/10

NOTE:
IF MANY BIRD SPECIES ARE PRESENT, AS WELL AS LARGE NUMBERS OF INDIVIDUALS OF ONE OR MORE (NON- INVASIVE) SPECIES, AND IF THE HABITAT DIVERSITY IS HIGH AND ITS AREA LARGE, THEN THE AREA SHOULD BE OF GREAT IMPORTANCE AS A HABITAT FOR BIRDS.

RULE NUMBER: 55

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the number of species of bird using the area during or just before, the period in question is high
and just before, or during, the period in question, there have been many individuals present
and wetland habitat diversity is high
and the extent of the wetland associated with the surface water feature is small

THEN:
the area could be an important habitat for the birds in question. - Probability=9/10

NOTE:
IF MANY BIRD SPECIES ARE PRESENT, AS WELL AS LARGE NUMBERS OF INDIVIDUALS OF ONE OR MORE (NON- INVASIVE) SPECIES, AND IF THE HABITAT DIVERSITY IS HIGH AND ITS AREA SMALL, THEN THE AREA COULD BE OF IMPORTANCE AS A HABITAT FOR BIRDS.

RULE NUMBER: 56

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the number of species of bird using the area during, or just before, the period in question is high
and just before, or during, the period in question, there have been NOT many individuals present
and wetland habitat diversity is high
and the extent of the wetland associated with the surface water feature is large

THEN:
the area could be an important habitat for the birds in question. - Probability=9/10

NOTE:
IF MANY BIRD SPECIES ARE PRESENT, AND IF THE HABITAT DIVERSITY IS HIGH AND THE WETLAND AREA LARGE, THEN THE AREA COULD BE OF IMPORTANCE AS A HABITAT FOR BIRDS.

RULE NUMBER: 57

IF:
the type of surface water feature is a coastal or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is
and recreation considered for the water surface area in question is powerboating
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the number of species of bird using the area during, or just before, the period in question is high
and the area could be an important habitat for the birds in question. Probability> 7/10

THEN:
consider prohibiting powered craft from using the area - Probability=10/10

RULE NUMBER: 58

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and recreation considered for the water surface area in question is yachting
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the number of species of bird using the area during, or just before, the period in question is high
and the area could be an important habitat for the birds in question. Probability> 7/10

THEN:
limit the number of yachts using the area over the period in question - Probability=10/10

RULE NUMBER: 59

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and recreation considered for the water surface area in question is boardsailing

and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the number of species of bird using the area during, or just before, the period in question is high
and the area could be an important habitat for the birds in question. Probability > 7/10

THEN:
consider prohibiting sailboards from using the area - Probability=9/10

RULE NUMBER: 60

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the number of species of bird using the area during, or just before, the period in question is high
and just before, or during, the period in question, there have been many individuals present

THEN:
the area could be an important habitat for the birds in question. - Probability=9/10

NOTE:
IF MANY BIRD SPECIES ARE PRESENT, AS WELL AS LARGE NUMBERS OF INDIVIDUALS OF ONE OR MORE (NON- INVASIVE) SPECIES, THE AREA COULD BE OF GREAT IMPORTANCE AS A HABITAT FOR BIRDS.

RULE NUMBER: 61

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the name of the bird in question is not relevant, but the number of species is,
and the number of species of bird using the area during, or just before, the period in question is high
and just before, or during, the period in question, there have been only one or two individuals present

THEN:
NOTE: ERROR DETECTED IN INPUT :There cannot be many or several species and yet only one or two individuals.

RULE NUMBER: 62

IF:
the type of surface water feature is a coastal lake or a vlei or an estuary
and the value of the area as a habitat for the bird(s) in question is considered to be low (i.e. not important) or unknown (of unknown importance for the bird(s))
and the area could be an important habitat for the birds in question. Probability > 7/10

THEN:
Investigate the feasibility of giving the surface water feature some conservation status (see further details) - Probability=9/10
and Protection of the bird habitat may be effected by:
(1) Registration under the RAMSAR CONVENTION as being of international importance.
(2) Being proclaimed as, or included in, a NATIONAL PARK (Nat. Parks Act, 1957) ; a Provincial, Municipal, or private nature reserve ; a nature reserve or Wilderness Area (Forest Act ,1968) ; or a Nature Area (Env. Cons. Act,1982)

RULE NUMBER: 63

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) Probability < 5/10
and powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) Probability > 0/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 3

RULE NUMBER: 64

IF:
consider prohibiting powered craft from using the area Probability < 5/10
and consider prohibiting powered craft from using the area Probability > 0/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 3

RULE NUMBER: 65

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) Probability = 5/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 5

RULE NUMBER: 66

IF:
consider prohibiting powered craft from using the area Probability = 5/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 5

RULE NUMBER: 67

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) Probability = 6/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 6

RULE NUMBER: 68

IF:
consider prohibiting powered craft from using the area Probability = 6/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 6

RULE NUMBER: 69

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) = 7/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 7

RULE NUMBER: 70

IF:
consider prohibiting powered craft from using the area Probability = 7/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 7

RULE NUMBER: 71

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details). Probability = 8/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 8

RULE NUMBER: 72

IF:
consider prohibiting powered craft from using the area Probability = 8/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 8

RULE NUMBER: 73

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) = 9/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 9

RULE NUMBER: 74

IF:
consider prohibiting powered craft from using the area Probability = 9/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 9

RULE NUMBER: 75

IF:
powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details) Probability = 10/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 10

RULE NUMBER: 76

IF:
consider prohibiting powered craft from using the area Probability = 10/10

THEN:
[NO POWERBOATS] IS GIVEN THE VALUE 10

RULE NUMBER: 77

IF:
the area could be an important habitat for the birds in question. Probability < 5/10
and the area could be an important habitat for the birds in question. Probability > 0/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 3

RULE NUMBER: 78

IF:
the area could be an important habitat for the birds in question. Probability = 5/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 5

RULE NUMBER: 79

IF:
the area could be an important habitat for the birds in question. probability = 6/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 6

RULE NUMBER: 80

IF:
the area could be an important habitat for the birds in question. Probability = 7/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 7

RULE NUMBER: 81

IF:
the area could be an important habitat for the birds in question. Probability= 8/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 8

RULE NUMBER: 82

IF:
the area could be an important habitat for the birds in question. Probability = 9/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 9

RULE NUMBER: 83

IF:
the area could be an important habitat for the birds in question. Probability = 10/10

THEN:
[HABITAT IMPORTANCE] IS GIVEN THE VALUE 10

QUALIFIERS:

1 the name of the bird in question is

Redknobbed Coot
Darter
Spurwing Goose
Egyptian Goose
Cape Shoveller
Yellowbill Teal
Redbill Teal
Cape Teal
Caspian Tern
any duck or goose (Anatidae)
unknown
other
not relevant, but the number of species is,

2 recreation considered for the water surface area in question is

powerboating
yachting
boardsailing
other

3 the type of surface water feature is

a coastal lake
a vlei
an estuary
other

4 just before, or over, the period in question the birds have been

roosting (not breeding) in the vicinity
breeding in the vicinity
present, but not roosting or breeding
roosting,but there is uncertainty as to whether they have been breeding

5 just before, or during, the period in question, there have been

only one or two individuals present
several individuals present
many individuals present

6 the value of the area as a habitat for the bird(s) in question is

considered to be high (i.e. important)
considered to be low (i.e. not important)
unknown (of unknown importance for the bird(s))

7 the period in question is

January
February
March
April
May
June
July
August
September
October
November
December
summer
autumn
winter
spring

8 (according to the S.A. Red Data Book - Birds (1984)), the bird is

RARE
ENDANGERED
VULNERABLE
INDETERMINATE
(note to reader: This qualifier is not used in AVIREC)

9 the number of species of bird using the area during, or just before, the period in question is

low
high
unknown or not applicable

10 the extent of the (natural) wetland associated with the surface water feature is

large
small

(Notes to Reader:
(1) Other rules could be constructed to determine these and intermediate values more accurately e.g.: IF % wetland is < 10% THEN the extent of the wetland associated with the surface water area is small.
(2) The term "wetland" needs to be defined in the rules in which it appears. EXSYS now has a help facility which the expert system developer can use to explain rule functions, terminology used and and other details for the user's benefit.)

11 habitat diversity is

relevant to this consultation
not relevant to this consultation
possibly relevant, but there is uncertainty as to whether this is the case.

12 wetland habitat diversity is

high
low
(Note to reader see comments under Qualifier 10)

CHOICES:

1 provide an alternative refuge for the species in question
(Note to reader: This choice is not used in AVIREC)
2 prohibit powerboat use during breeding season
(Note to reader: This choice is not used in AVIREC)

3 prohibit sailcraft use during breeding season of the species in question
(Note to reader: This choice is not used in AVIREC)

4 limit the number of powerboats using the area over the period in question

5 limit the number of yachts using the area over the period in question

6 limit the number of sailboards using the area over the period in question
(Note to reader: This choice is not used in AVIREC)

7 apply speed limits to powered craft in the vicinity during the period in question.

8 powered craft should be kept well away from breeding/ roosting area(s) during the period specified (see further details)

9 sailboards and their occupants should be kept away from the breeding/roosting area during the period specified (see further details)

10 yachts should be kept away from the breeding/ roosting area during the period specified (see further details)

11 contact bird specialists for further advice.

12 review available literature on the importance of the surface water feature as a bird habitat (see further for recommendations).

13 identify birds with the help of a specialist and, if needed, an identification manual.

14 Investigate the feasibility of giving the surface water feature some conservation status (see further details)

15 consider prohibiting powered craft from using the area

16 contact a fish specialist for advice on the impact of powered craft on any fish populations present .

17 the bird in question is breeding in the vicinity.

18 the bird in question is roosting in the vicinity.
(Note to reader: This choice is not used in AVIREC)

19 powered craft should be kept well away from the roosting area during the period in question

20 yachts should be kept well away from the roosting area during the period in question

21 sailboards and their occupants should be kept well away from the roosting area during the period in question

22 limit the number of sailing craft using the water surface area over the period in question

23 consider the prohibition of all craft in the area over the period in question
(Note to reader: This choice is not used in AVIREC)

24 the area could be an important habitat for the birds in question.

25 sailboards and their occupants should be kept well away from the roosting area during breeding season
(Note to reader: This choice is not used in AVIREC)

26 consider prohibiting sailboards from using the area

VARIABLES:

1 BIRD EXPERT ADDRESS
For bird specialists,contact :
P.G. Ryan, R.K. Brooke, P.A.R. Hockey
Ornithology, University of Cape Town,
Private Bag, Rondebosch,
CAPE TOWN 7700
Phone: (021)-6509111
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Displayed at the end of a run

2 BIRD HABITAT REF
NOTE:- Further details on the importance of the surface water feature as a bird habitat may be found in:- Cooper,J. ,Hockey, P.A.R. and Ryan, P.G. 1987/8 : An Atlas of Coastal Birds of Southern Africa, Percy Fitzpatrick Institute, University of Cape Town. (in press).
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3 BIRD IDENTITY
NOTE:- To facilitate the identification of birds, consult: Newman,K.B., 1983: NEWMANS BIRDS OF SOUTHERN AFRICA, Macmillan, Johannesburg.
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Displayed at the end of a run

4 NATURE RESERVES
Protection of the bird habitat may be effected by: (1) Registration under the RAMSAR CONVENTION as being of international importance.
(2)Being proclaimed as,or included in,a NATIONAL PARK (Nat.Parks Act, 1957); a Provincial, Municipal, or private nature reserve; a nature reserve or Wilderness Area (Forest Act ,1968); or a Nature Area (Env.Cons. Act,1982)
Displayed at the end of a run as text only
Displayed at the end of a run

5 FISH EXPERT ADDRESS
Estuarine fish experts are:
Bruce Bennet and Glynnis Bleckley,
Zoology Dept., University of Cape Town,
Private Bag,RONDEBOSCH 7700.
Ph:6509111
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Displayed at the end of a run

6 RARE BIRD
the bird is classified as RARE in the S.Afr.Red Data Book - Birds (Brooke,R.K., 1984)
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Displayed at the end of a run

7 CASPIAN ROOST SITES
NOTE:- Caspian Tern roost on the banks or slopes around estuaries, or on mudbanks,sandbanks and islands in estuaries and wetlands, provided these sites are undisturbed.
Displayed at the end of a run as text only
Displayed at the end of a run

8 CASPIAN BREED SEASON
NOTE: In the western Cape, Caspian Tern breed in Dec./Jan
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9 BIRD NUMBER ERROR
NOTE: ERROR DETECTED IN INPUT :There cannot be many or several species and yet only one or two individuals.
Displayed at the end of a run as text only
Displayed at the end of a run

10 NO POWERBOATS
The indication of the need for prohibition of powerboats in the area over the period in question, on a scale of 1 to 10
Numeric variable

11 HABITAT IMPORTANCE
the likelihood of the surface water feature being important for birds, on a scale of 1 to 10
Numeric variable

A P P E N D I X V I I

G E N R E C : R U L E S, Q U A L I F I E R S, C H O I C E S A N D V A R I A B L E S

Subject:
The assimilation of expert advice and decisions from SEWAGE, PHYSREC and AVIREC and the use of more general information so as to aid in deriving overall solutions to a problem.

RULES:

RULE NUMBER: 1

IF:
[EUTROPHICATION]<5
and [HI CONG FACTOR]<1
and Management priorities for the area are towards recreation
and [NO POWERBOATS]<5
and [HABITAT IMPORTANCE]<5

THEN:

no significant problems are foreseen with regard to eutrophication by septic tank effluent seepage, recreational congestion involving craft and the effect of boating activities on aquatic avifauna in the surface water feature in question - Probability=7/10

RULE NUMBER: 2

IF:
[EUTROPHICATION]>4
and [HI CONG FACTOR]<1

and Management priorities for the area are towards recreation

and [EUTROPHICATION]<8

THEN:

set the proposed resort further back from the boundary of the surface water feature, estimate the new setback distance and re-run SEWAGE to determine the change in the likelihood of significant eutrophication occurring in portions of the surface water feature - Probability=5/10

RULE NUMBER: 3

IF:
[EUTROPHICATION]>7
and [HI CONG FACTOR]<1
and Management priorities for the area are towards recreation

THEN:

set the proposed resort further back from the boundary of the surface water feature, estimate the new setback distance and re-run SEWAGE to determine the change in the likelihood of significant eutrophication occurring in portions of the surface water feature - Probability=7/10

RULE NUMBER: 4

IF:
[EUTROPHICATION]<5
and [HI CONG FACTOR]<1
and Management priorities for the area are towards conservation
and [NO POWERBOATS]<5
and [HABITAT IMPORTANCE]<5

THEN:

no significant problems are foreseen with regard to eutrophication by septic tank effluent seepage, recreational congestion involving craft and the effect of boating activities on aquatic avifauna in the surface water feature in question - Probability=5/10

RULE NUMBER: 5

IF:

[EUTROPHICATION]>4
and [HI CONG FACTOR]<1
and Management priorities for the area are towards conservation
and [EUTROPHICATION]<8

THEN:

reduce the number of erven proposed, then recalculate the average size of erven and re-run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature - Probability=8/10

and set the proposed resort further back from the boundary of the surface water feature, estimate the new setback distance and re-run SEWAGE to determine the change in the likelihood of significant eutrophication occurring in portions of the surface water feature - Probability=7/10

RULE NUMBER: 6

IF:

[EUTROPHICATION]>7
and [HI CONG FACTOR]<1
and Management priorities for the area are towards conservation

THEN:

reduce the number of erven proposed, then recalculate the average size of erven and re-run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface waterfeature - Probability=8/10

and set the proposed resort further back from the boundary of the surface water feature, estimate the new setback distance and re-run SEWAGE to determine the change in the likelihood of significant eutrophication occurring in portions of the surface water feature - Probability=9/10

RULE NUMBER: 7

IF:

[EUTROPHICATION]<=7
and [HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards conservation
and [EUTROPHICATION]>=5

THEN:

reduce the number of erven proposed, recalculate the average size of erven, then run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=8/10

and Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=4/10

RULE NUMBER: 8

IF:

[EUTROPHICATION]>=8
and [HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards recreation

THEN:

reduce the number of erven proposed, recalculate the average size of erven, then run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=9/10

and reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=4/10

RULE NUMBER: 9

IF:

[EUTROPHICATION]<5
and [HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards conservation

THEN:

Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=7/10

and limit the numbers of craft concerned, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the new limits - Probability=6/10

RULE NUMBER: 10

IF:

[EUTROPHICATION]<8
and [HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards recreation
and [EUTROPHICATION]>=5

THEN:

reduce the number of erven proposed, recalculate the average size of erven, then run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=8/10

and Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=4/10

RULE NUMBER: 11

IF:

[EUTROPHICATION]<5
and [HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards recreation

THEN:

Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=6/10

and limit the numbers of craft concerned, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the new limits - Probability=6/10

RULE NUMBER: 12

IF:

[EUTROPHICATION]>7
and [HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards conservation

THEN:

reduce the number of erven proposed, recalculate the average size of erven, then run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=9/10

and Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=5/10

RULE NUMBER: 13

IF:
[HI CONG FACTOR]<1
and recreation considered for the area in question is powerboating
and [NO POWERBOATS]>=5
and Management priorities for the area are towards recreation

THEN:

prohibit powered craft from using the area in question -Probability=7/10

and investigate the emplacement or removal of barriers (e.g. fences,certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=8/10

and consider turning down the development proposal. - Probability=6/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=6/10

RULE NUMBER: 14

IF:
[HI CONG FACTOR]<1
and recreation considered for the area in question is powerboating
and [NO POWERBOATS]>=5
and Management priorities for the area are towards conservation

THEN:

prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=8/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface waterfeature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=5/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=8/10

and consider turning down the development proposal. - Probability=7/10

RULE NUMBER: 15

IF:
[HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards conservation

THEN:

Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=8/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=8/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=8/10

and consider turning down the development proposal. - Probability=7/10

and prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=8/10

RULE NUMBER: 16

IF:
[HI CONG FACTOR]>=1
and recreation considered for the area in question is powerboating
and [NO POWERBOATS]>=5
and Management priorities for the area are towards conservation

THEN:

prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=9/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=9/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=9/10

and consider turning down the development proposal. - Probability=8/10

and Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=8/10

RULE NUMBER: 17

IF:
[HI CONG FACTOR]>=1
and [NO POWERBOATS]<5
and Management priorities for the area are towards recreation

THEN:

prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=7/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=8/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=8/10

and consider turning down the development proposal. - Probability=5/10

and Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=7/10

RULE NUMBER: 18

IF:
[HI CONG FACTOR]>=1
and recreation considered for the area in question is powerboating
and [NO POWERBOATS]>=5
and Management priorities for the area are towards recreation

THEN:

prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=8/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=8/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=7/10

and consider turning down the development proposal. - Probability=6/10

and Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=7/10

RULE NUMBER: 19

IF:

[HI CONG FACTOR]>=2
and Management priorities for the area are towards recreation

THEN:

Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=9/10

and prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=9/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=10/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=10/10

and consider turning down the development proposal. - Probability=8/10

RULE NUMBER: 20

IF:

[HI CONG FACTOR]>=2
and Management priorities for the area are towards conservation

THEN:

Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=10/10

and prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=10/10

and investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walks) - Probability=10/10

and investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned - Probability=10/10

and consider turning down the development proposal. - Probability=9/10

RULE NUMBER: 21

IF:
[HI CONG FACTOR]>=3
and Management priorities for the area are towards conservation

THEN:

consider turning down the development proposal. - Probability=10/10

RULE NUMBER: 22

IF:
[HI CONG FACTOR]>=3
and Management priorities for the area are towards recreation

THEN:

Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned - Probability=10/10

and prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft. - Probability=10/10

and consider turning down the development proposal. - Probability=9/10

RULE NUMBER: 23

IF:
[HABITAT IMPORTANCE]>=5
and [HABITAT IMPORTANCE]<8
and Management priorities for the area are towards recreation
and recreation considered for the area in question is powerboating

THEN:

place strict controls on any powerboating in the area concerned - Probability=6/10

RULE NUMBER: 24

IF:
[HABITAT IMPORTANCE]>=5
and [HABITAT IMPORTANCE]<8
and Management priorities for the area are towards recreation
and recreation considered for the area in question is boardsailing

THEN:

place strict controls on any boardsailing in the area concerned - Probability=3/10

RULE NUMBER: 25

IF:
[HABITAT IMPORTANCE]>=5
and [HABITAT IMPORTANCE]<8
and Management priorities for the area are towards conservation
and recreation considered for the area in question is powerboating

THEN:

place strict controls on any powerboating in the area concerned - Probability=8/10

RULE NUMBER: 26

IF:
[HABITAT IMPORTANCE]>=5
and [HABITAT IMPORTANCE]<8
and Management priorities for the area are towards conservation
and recreation considered for the area in question is boardsailing

THEN:

place strict controls on any boardsailing in the area concerned - Probability=5/10

RULE NUMBER: 27

IF:

[HABITAT IMPORTANCE]>=8
and [HABITAT IMPORTANCE]<10
and Management priorities for the area are towards recreation
and recreation considered for the area in question is powerboating

THEN:

place strict controls on any powerboating in the area concerned - Probability=8/10

RULE NUMBER: 28

IF:

[HABITAT IMPORTANCE]>=8
and [HABITAT IMPORTANCE]<10
and Management priorities for the area are towards recreation
and recreation considered for the area in question is boardsailing

THEN:

place strict controls on any boardsailing in the area concerned - Probability=5/10

RULE NUMBER: 29

IF:

[HABITAT IMPORTANCE]>=8
and [HABITAT IMPORTANCE]<10
and Management priorities for the area are towards conservation
and recreation considered for the area in question is powerboating

THEN:

place strict controls on any powerboating in the area concerned - Probability=10/10

and consider turning down the development proposal. - Probability=9/10

RULE NUMBER: 30

IF:

[HABITAT IMPORTANCE]>=8
and [HABITAT IMPORTANCE]<10
and Management priorities for the area are towards conservation
and recreation considered for the area in question is boardsailing

THEN:

place strict controls on any boardsailing in the area concerned - Probability=7/10

and consider turning down the development proposal. - Probability=9/10

RULE NUMBER: 31

IF:

[HABITAT IMPORTANCE]=10
and recreation considered for the area in question is powerboating

THEN:

place strict controls on any powerboating in the area concerned - Probability=10/10

RULE NUMBER: 32

IF:

[HABITAT IMPORTANCE]=10
and recreation considered for the area in question is boardsailing

THEN:

place strict controls on any boardsailing in the area concerned - Probability=9/10

QUALIFIERS:

1 Management priorities for the area are
towards conservation
towards recreation

2 recreation considered for the area in question is

powerboating
yachting
boardsailing
other

CHOICES:

1 reduce the number of erven proposed, then recalculate the average size of erven and re-run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature

2 reduce the number of erven proposed, recalculate the average size of erven, then run SEWAGE to determine the change in likelihood of significant eutrophication occurring in portions of the surface water feature, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned

3 set the proposed resort further back from the boundary of the surface water feature, estimate the new setback distance and re-run SEWAGE to determine the change in the likelihood of significant eutrophication occurring in portions of the surface water feature

4 consider using alternative methods for the disposal of sewage effluent.

5 prohibit powerboats from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft.

6 limit the numbers of craft concerned, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the new limits

7 prohibit sailboards from using the area in question, then run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for other craft

8 consider turning down the development proposal.

9 investigate the possibility of providing alternative recreational facilities so as to reduce recreational pressure on the surface water feature in question (e.g. a boat ramp to sea, a tidal pool, scenic walk)

10 investigate the emplacement or removal of barriers (e.g. fences, certain vegetation, mounds) and corridors (e.g. pathways, raised boardwalks, roads) to direct specific recreational activities away from the area concerned

11 no significant problems are foreseen with regard to eutrophication by septic tank effluent seepage, recreational congestion involving craft and the effect of boating activities on aquatic avifauna in the surface water feature in question

12 Reduce the number of erven proposed, recalculate the average size of erven, then re-run PHYSREC to re-estimate the likelihood of exceeding the physical recreation carrying capacity for the revised numbers of craft predicted to be using the area concerned

13 place strict controls on any powerboating in the area concerned

14 place strict controls on any boardsailing in the area concerned

15 prohibit powered craft from using the area in question

VARIABLES:

1 EUTROPHICATION
the likelihood of significant eutrophication of portions of the surface water feature from seepage of septic tank effluent, on a scale of 1 to 10
Numeric variable
Displayed at the end of a run

2 HI CONG FACTOR
the product of the congestion factor, CF, and the ratio HIGH PROPORTION obtained from PHYSREC Numeric variable
Displayed at the end of a run

3 NO POWERBOATS
the weighting given to the (AVIREC) management option: "prohibit powerboats from using the area over the period in question"
Numeric variable
Displayed at the end of a run

4 LIMIT CRAFT NOS
the weighting given to the (AVIREC) management option "limit the total number of craft in question"
Numeric variable
Displayed at the end of a run

5 HABITAT IMPORTANCE
the likelihood of the surface water feature being important for birds,as obtained from AVIREC
Numeric variable
Displayed at the end of a run